THE McGRAW-HILL MAGAZINE FOR DESIGN ENGINEERS

SEPT. 18, 1961

PRICE 50 CENTS

LUBRICANTS

Oil synthetics, greases, additives—which are best for your design

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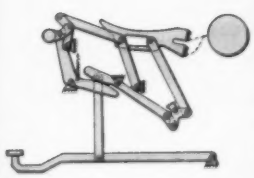
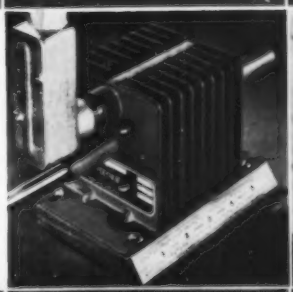
PRODUCT ENGINEERING

MECHANISMS



ACTUATORS



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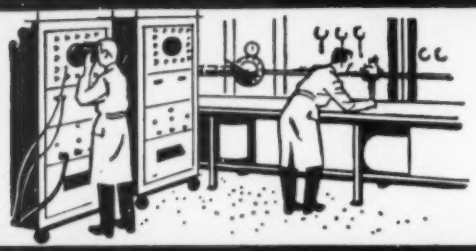

Out of the **Ross** research lab has passed the most extensive line of valves in the air control world

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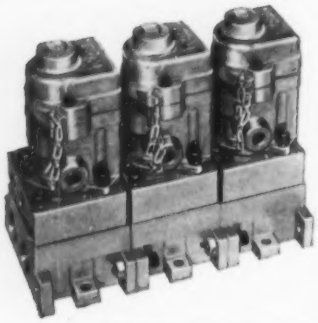

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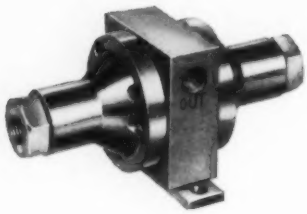
The PACER 4-way gives 1000 cpm and more, has all JIC features, is built for super long life. Manifold as many as you please. One air supply, one exhaust.

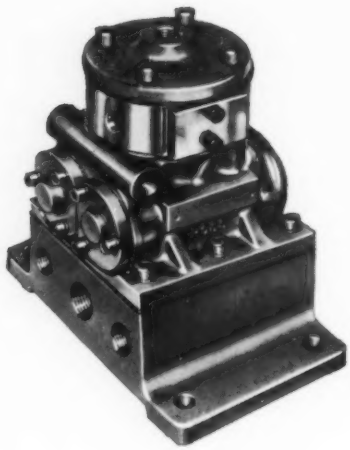
For greater press safety

The Non-Tie-Down valve is designed to protect the press operator's hands. Requires the operator to activate two separate valves continuously during a machine's cycle.



Overriding cam operation

The PCB valve—A ¼" valve with low minimum operating pressure—5 psi to 125 psi—that is fast operating and ruggedly built. Overriding cam activates valve from one direction only.



Air operation with momentary action on a 4-way, 5-port

Need to send a cylinder home hard but return it softly . . . or vice versa? This 4-way, 5-port lets you supply two different pressures to the cylinder. And the air index adaptor gives you momentary action. The main valve reverses and stays put with each air impulse delivered to the air operated head.

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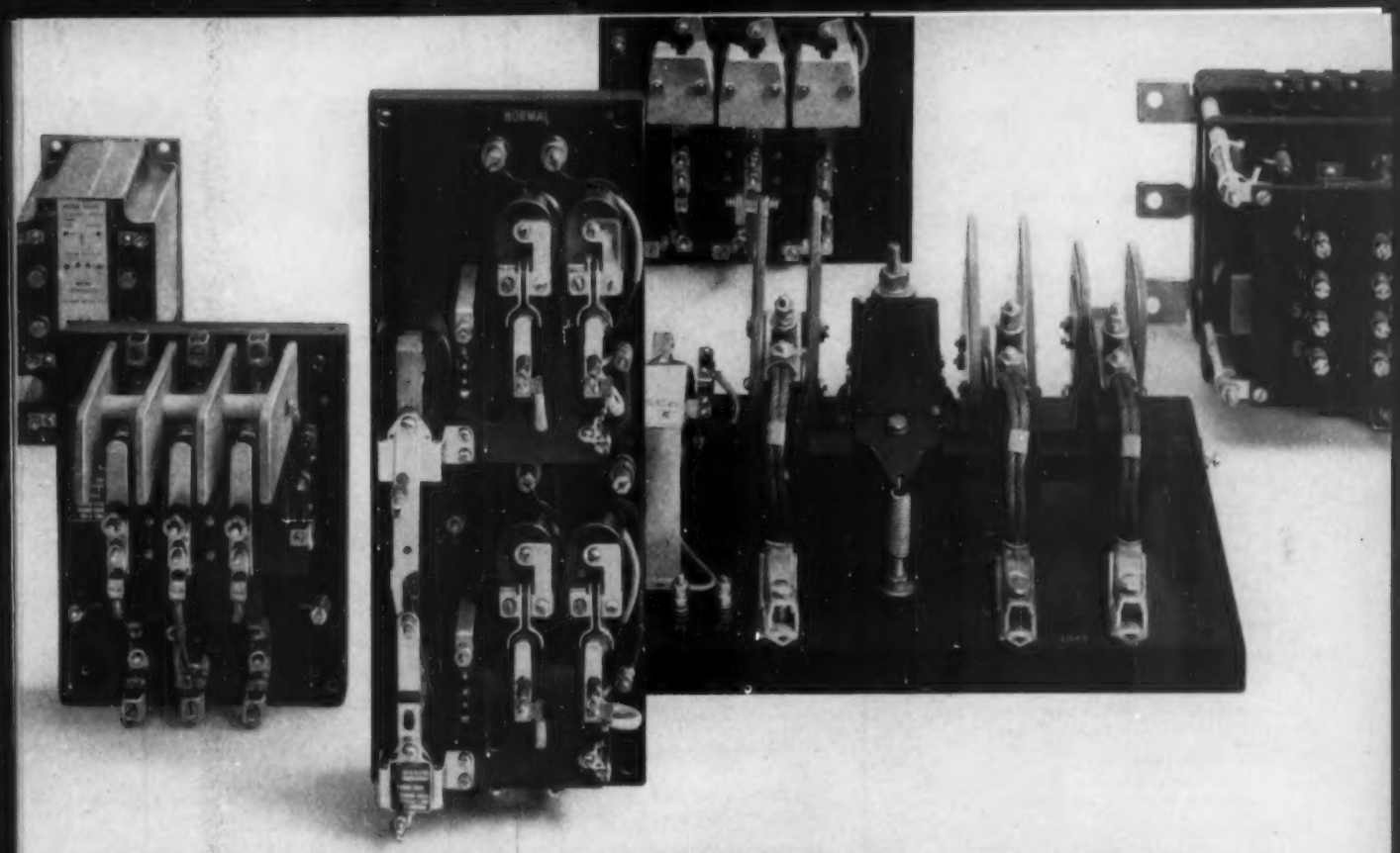
CIRCLE 173 ON READER SERVICE CARD



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The tremendous variety of "regular" contactor designs produced by ASCO is the outgrowth of unequalled experience in the engineering of "special" control mechanisms. While this know-how *can* be put to work to resolve your unusual control problem, chances are that the solution is already on an ASCO shelf.

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They have several advantages for remote, precise indication and control in the in.-oz range.

Rules for Cooling with Blowers

Simple "rights" and "wrongs" on placement, sizing and enclosures for best results.

8 Control Mountings

Ways to place and lock knobs on control panels.

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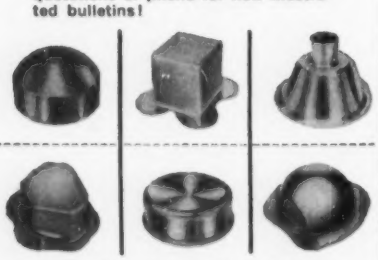

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METAL CRAFTSMEN
SINCE 1924

HORIZONS

F. Langenau

Redesign for Tomorrow

Some months ago, in a plant making electric fans, I saw a particular model something over 20 years old. My engineer guide explained that it still sold a tidy total each year, so no changes had been made beyond the expected ones in insulation and motor materials to meet modern requirements. It's now seriously challenged by air conditioning anyhow. . .

This is in sharp contrast to the annual model change, even to the practice of one company of making model changes whenever the dies wear out, or that of Volkswagen in changing without date or fanfare.

Our own philosophy is a sort of mixture, because a magazine is in one sense a new product each issue, although the "package" doesn't change so frequently.

Four years ago, we made a major redesign in *Product Engineering*, and since that time have added features and tested various refinements. Many you have liked, as evidenced by a rise in circulation of more than a third, in subscription renewals of more than 10%, and in letters and postcards a tripling or quadrupling. We've also picked up a number of awards in journalism and public service—three last year.

But in this business you can't stand still. When you think of how the design field has changed in four years, then it is obvious that the publication which was good enough then is not good enough today. Further refinement of the design and a sound cost analysis were obviously needed, as well as good industrial design.

Our new product is represented by the current issue. In it you'll find all of your preferred services, some in different places, some with new names or faces, but in every case incorporating the results of our studies and your comments.

This is not simply two former issues combined in one; it is a complete redesign to make *Product Engineering* even more usable and readable. Here are some of the changes:

1. The cover is distinctive, different, features articles which we think will interest you particularly.
2. The contents page becomes two pages, so we can provide more detail describing each article, as well as predict what will come in the next issue.
3. "Horizons" will hereafter appear as a column rather than an editorial.
4. "Interesting to Note," a unique element in technical journals, moves back a page or two.
5. "The Engineering Week" disappears as such, short news items being included in "Developments to Watch" (the front yellow pages), the longer studies and roundups appearing as articles.
6. Articles are grouped in a single section, uninterrupted by advertising. A newer, more-readable type face and a very-new head type should make things easier for those of you who, like me, are resigned to bifocals. Illustration techniques have been improved as well.
7. A new "do-it-yourself" section on yellow stock at the rear of the magazine includes the first instalment of a new series on mathematics, a data sheet, and the popular department, "Why Don't They R & D?."
8. We have returned to the staple-less binding that you liked so well and are again wrapping the copies to reduce damage in handling.

We think the result of all these changes is a more-usable working handbook that sets a new standard in business journalism. But then we've always felt that the men responsible for creating America's engineered

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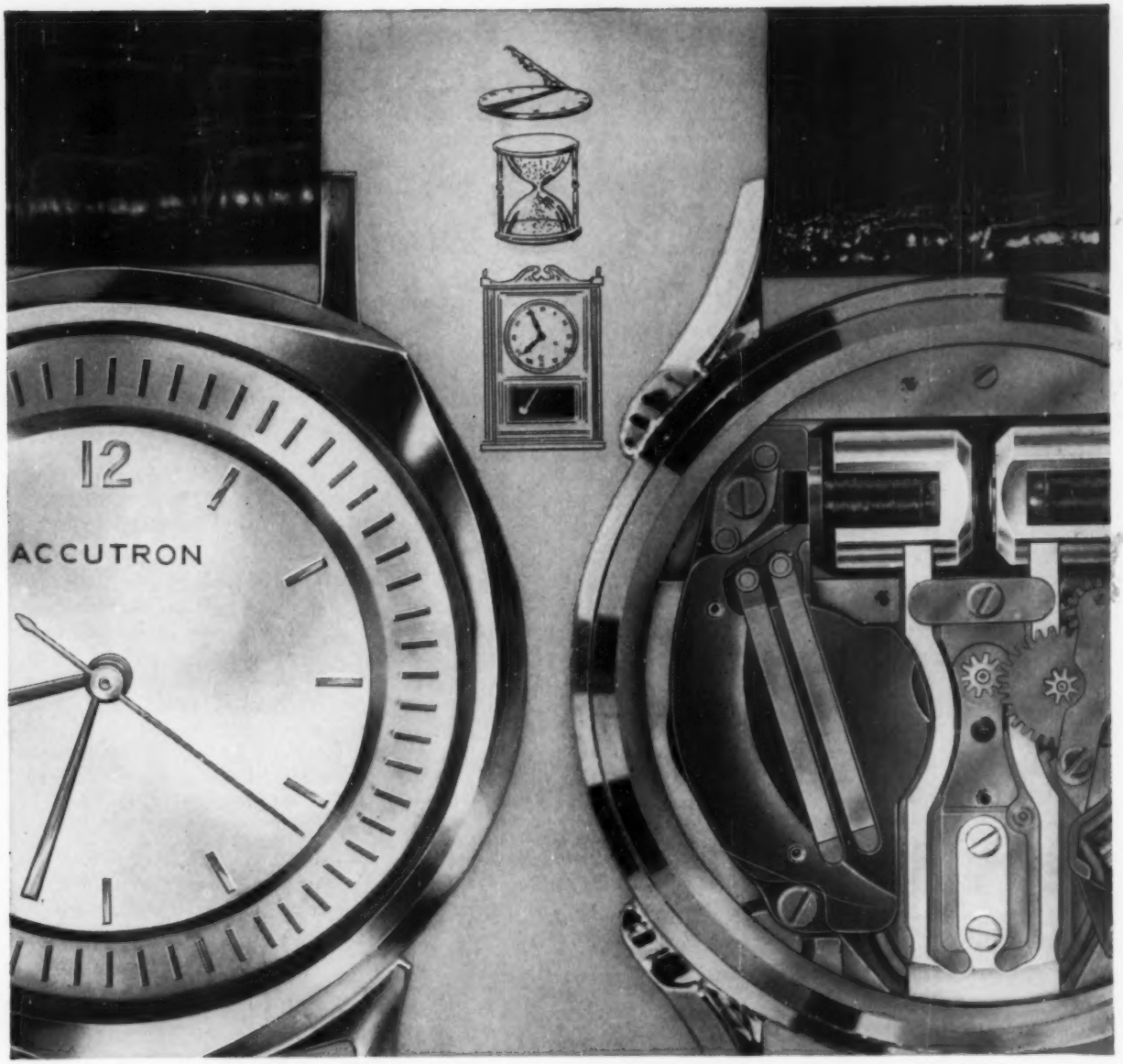

How Nickel helps make timekeeping history

Electronic tuning fork made of a Nickel alloy represents the most basic advance in personal timekeeping in 300 years

A watch you don't need to wind. A watch without mainspring, balance wheel, or hairspring. A watch that doesn't gain or lose more than 2 seconds out of every 86,400!

The secret of the fantastic timekeeping accuracy of Accutron* is a precision tuning fork that vibrates more than 31 million times every twenty-four hours—day after day, week after week, month after month...powered by a button-size battery.

To assure the faultless, electronic measurement of time, the tuning fork's incessant vibration must remain constant under a wide range of temperatures and all sorts of shock and impact that can occur in day-to-day watch wear.

That's why electronic engineers chose Ni-Span-C† alloy (42% Nickel) for the heart of this space-age marvel. This high Nickel alloy maintains the fork's vital stiffness at temperatures from 0° to 150° F...fights off damaging corrosion and oxidation.

Just as Nickel helps give this watch's mechanism exceptional reliability, so too Nickel can increase the reliability of hundreds of alloys under many severe conditions—great heat, cold, corrosion, or stress. Alone, or with other elements, Nickel gives alloys the combination of properties to meet the most demanding metals needs.

Perhaps Nickel or a Nickel alloy can help solve your metal problem. To find out, just write to Inco.

*Bulova Watch Company, Inc. trademark.
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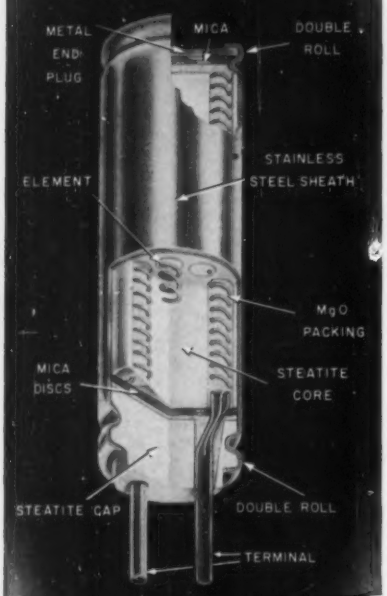

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HORIZONS *continued*

products deserve and expect a correspondingly well-designed and properly produced magazine. Our product, like yours, must be up to date in design and function and must incorporate the new developments to make it better.

We hope you like it, and will continue to give us the benefit of your advice and suggestions.

• • • •

"Writing books about other people's books is an occupational hazard of college professors," says L F Urwick, famous English management engineer. He feels only applied scientists should write books—using new experimental data. That's one problem of the pragmatic man; he understands eating but not digestion, doing but not thinking. Unless it can be seen or felt, the thing is no good.

"Too often our Washington reflex is to discover a problem, and then throw money at it, hoping it will go away."—*Sen Kenneth B Keating,* opposing proposed government subsidies for political campaign costs.

Pythagoras established the first management school in Crotona, Italy, in 559 BC. His purpose was to educate the sons of landowners and merchant princes so they could protect themselves against enemies who might attempt to subvert local tenant farmers and day laborers. This was the usual way for one city to begin conquest of another. Pythagoras himself, a philosopher, ultimately died of starvation in the Temple of Muses. He'd gone there for asylum against assassins, and was finally forced to choose between going out and being stabbed to death, or staying in without food. Even then, you see, anybody who attacked the "cultural lag" (as sociologists call technological advance) took long chances.

"Mind—A mysterious form of matter secreted by the brain. Its chief endeavor consists of ascertaining its own nature. The futility of its attempt is due to the fact that it has nothing but itself to know itself with."

—Ambrose Bierce

"History is the whisper of slippered feet coming down the stairs, drowned out by the thunder of hobnailed boots on the way up."

—Anonymous

"The fundamental characteristic of the manager of scientific and technical personnel is that he is *not* a status seeker. We must "debunk" the manager's status. I don't mind his larger paycheck; he deserves a lot of pay because he's doing the less-interesting, and maybe the less-significant, work. He ought to be compensated for not having the fun of the technological work, but we must control his status and his authority so that he can actually be a *servant* of the technologists whom he manages.

"They need a servant, they need an interpreter, they need a translator, they need a salesman, they need an organizer, but they do *not* need an authority because *they* are the authorities. They have the authority of knowledge, as far as they go, and they're going farther and farther every day. To manage them requires a new kind of man.

"I happen to have the unorthodox notion that we have never understood the function of the German general-staff officer. It was the development of that officer, who was a mediator between the technologists and the line command, that enabled the German army twice to be technologically way ahead of its opponents and to shoot a whole lot more people per dollar than those lined up on the other side."

—Francis F Bradshaw, consultant, GE Institute for Advanced Management, Crotonville-on-Hudson, N Y

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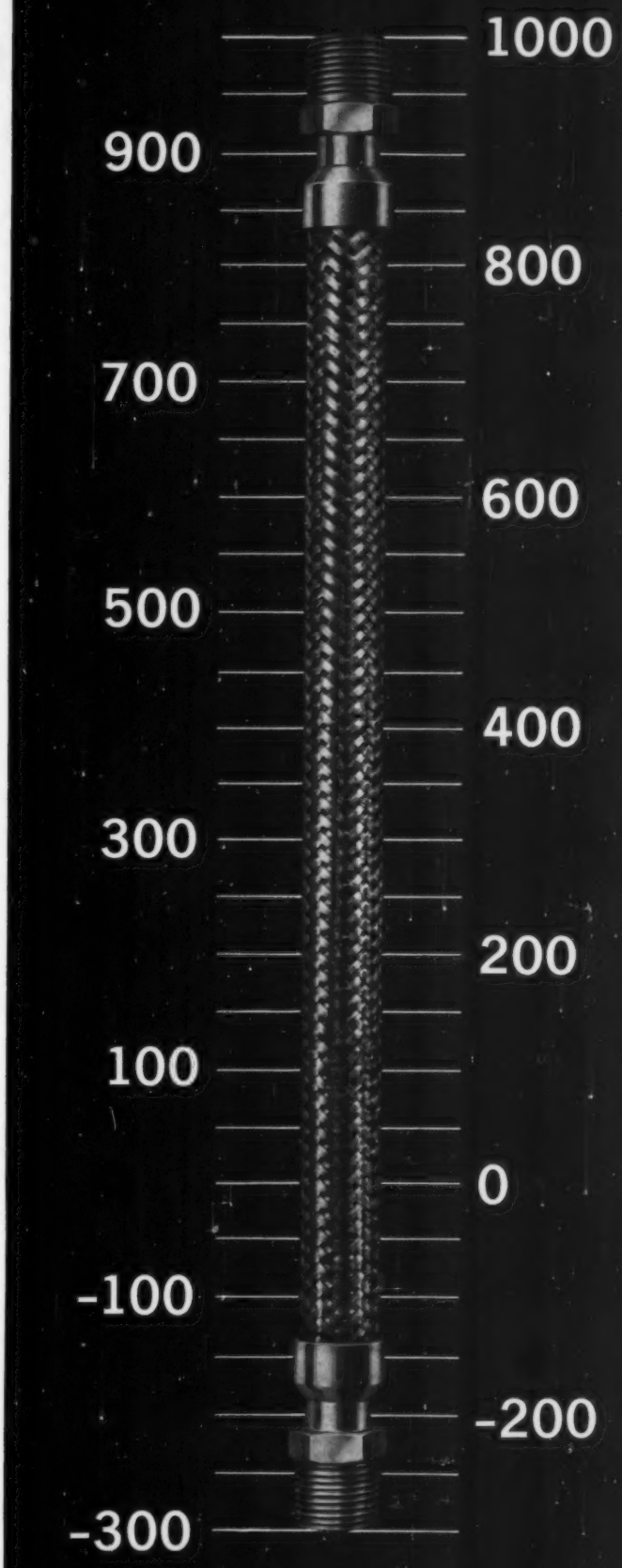

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R/M POLY-V® "J" DRIVE is industry's newest and most revolutionary light-duty drive for small diameter sheaves, short centers and compact units. It utilizes a single parallel V-ribbed belt running on space-saving sheaves grooved to mate precisely with the belt ribs. Design advantages of Poly-V "J" add up to more dependable power in less drive space wherever balance and highly efficient, silent, vibration-free drive performance are required.

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- **Designed especially for small sheaves; considerably below V-belt range**
- **Silent, vibrationless, cool operation; homogeneous traction surface is spliceless, lapless**
- **No belt matching; a single belt cross section meets every need from 1/40 to 15 HP**
- **Delivers much more load in less space; permits more compact drive with smaller mounting clearances**
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- **Minimum drive wear; assures longer belt and sheave life**
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- **Complete contact pressure; maintains groove shape**
- **Heat and Oil Resistant**

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For medium and heavy duty drives, R/M Poly-V* is available in the larger "L" and "M" Sections. These 3 Poly-V Belts (J, L and M) will replace 8 V-belt size sections and cover a power range from 1/40 to 1700 HP. Wherever your design problems involve power transmission drives, V-belts, flat belts . . . rely on R/M products and engineering.

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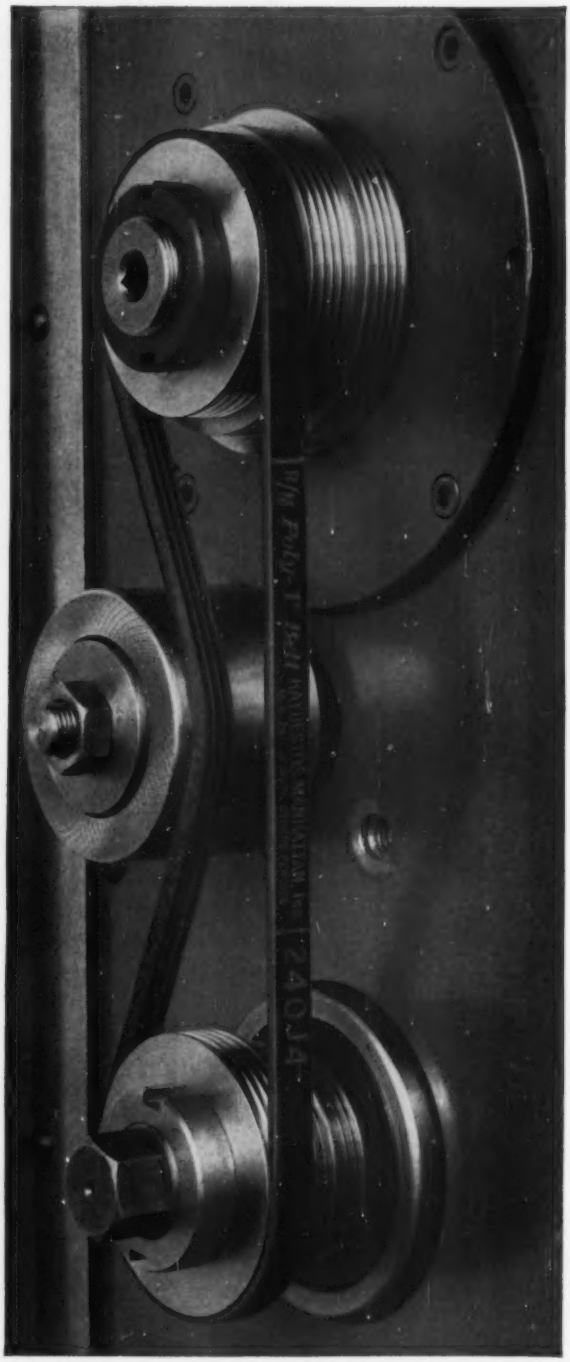


Poly-V "J" on Parker Majestic Grinder as standard equipment

sintered metal, and engineered plastic products

BOND FAILURES CAN BE PREVENTED!

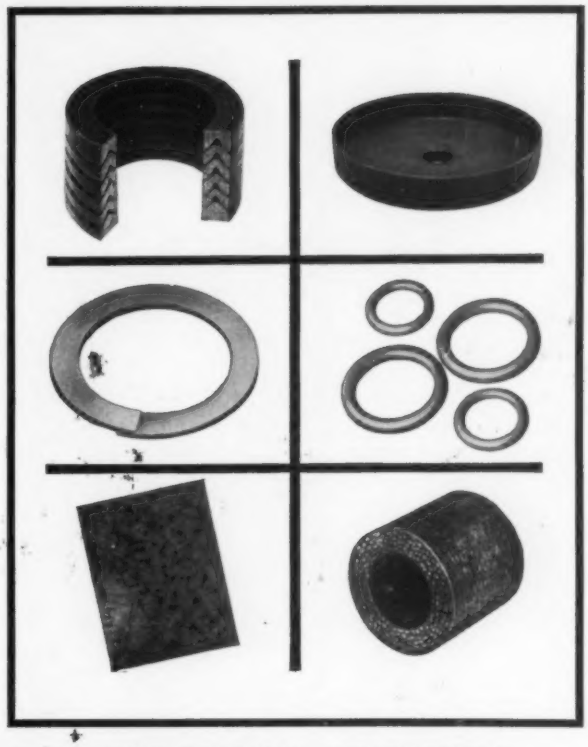
Here's how to stop 13 of them . . .

Type of Failure	Solution
THERMOSETTING ADHESIVES	
• Cohesive failure	Check film with solvent used in adhesive. If solvent softens the adhesive film or becomes tacky, this indicates insufficient cure. Make sure bond line time and temperature is used.
• Adhesive failure from metal	If metal surface has a white, clean appearance, check cleaning technique.
• Adhesive failure from substrate other than metal	Try prime coat of diluted adhesive, also check compatibility.
• Cellular areas in adhesive line	Increase pressure and/or adhesive.
CONTACT ADHESIVES —room temperature setting	
• Tacky film	If film should dry hard but remains tacky, the cause may be entrapped solvent or migration of plasticizer from one substrate.
• Shiny areas	Poor contact, insufficient pressure or insufficient amount of cement.
• No bond	If heat reactivated type, adhesive was too cool at time of assembly or poor compatibility.
• Failure in adhesive from metal	Improper cleaning.
• From substrate other than metal	Incompatible or unclean surfaces.
HOT MELT	
• No bond	Incompatibility, adhesive too cool at time of assembly. Parts too cool at time of application of adhesive.
EPOXY BASE ADHESIVES AND CASTING COMPOUNDS	
• High exotherm	Mix lower volume and pour mixed material into shallow tray. Cool base and activator before mixing or use Metermixing equipment.
• Tacky film or casting	Improper base activator ratio, improper mixing of base and activator, improper cure. Check bond line temperature.
• Flexible casting or film of rigid adhesive or casting compound	Improper mixing of base and activator, improper base and activator, improper cure. Check bond line temperature.

Bond failures can be prevented! Raybestos-Manhattan's adhesive experts also have solutions to less common causes of bond failures . . . based on more than 20 years' experience in the production of bonded assemblies and the manufacture of adhesives, coatings and sealers. Why not call on them today for the answers to your adhesive problems—no cost or obligation, naturally.

ADHESIVES

Get helpful engineering information on selecting, bonding and testing adhesives. Write today for your free copy of Bulletin No. 701. Adhesives Department, Raybestos-Manhattan, Inc., Bridgeport, Conn.



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to lower friction, eliminate contaminating lubricants, resist corrosion and extrusion

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Gears formed of Texin urethane elastomer by fast, low-cost injection molding methods give you mass production economy with consistent uniformity of dimensions without machining.

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Now Texin lets you mold gears that are shock-absorbing, silent running, shatter-proof and self-lubricating. For more information on how to put this heavy-duty elastoplastic to work for you, write Mobay Chemical Company, Code PN-19, Pittsburgh 5, Pa.

To keep posted on new application developments for Texin, ask to be placed on the TEXIN TOPICS mailing list . . .

MOBAY

e-9

SPACE A-24 Plastics Show of Canada, Toronto, October 17-19

INTERESTING TO NOTE

ALTHOUGH James Watt is credited with the invention of the steam engine, much of his work was based upon engines designed by Newcomen and Savery. In 1712, for example, Thomas Newcomen built an engine that worked with steam at atmospheric pressure. By condensing the steam in a cylinder, a partial vacuum was created which allowed atmospheric pressure to force the piston down.

To harness the downward pull of the piston, Newcomen linked the piston to a rocker arm or "walking beam". This mechanical rocking mechanism was an early version of those described on page 65. The vacuum produced in the cylinder pulled the beam down; when the vacuum was broken, a counterweight on the beam returned it to its original position. The ends of the beams were shaped in circular arcs centered on the beam pivot so that chains attached to the arcs would pull piston rod and counterweight up in straight lines.

It was necessary to open and close the steamvalves or "injection cocks" at the proper time by hand. The story is that Newcomen hired Humphrey Potter to open and close the valves. The boy preferrred fishing. So with "catches and strings" or "scoggans" Humphrey developed a method of tripping the valve each time the beam reached the proper position. There is no confirmation of the legend of Humphrey Potter and it probably belongs with the later legend of Watt and the teakettle or Ben Franklin and his kite.

When Watt undertook the task of improving the Newcomen engine, he quickly discovered its limitations. His problems were not just in the field of design. He found serious limitations in the area of metal cutting—there were no machines available that could meet close tolerances. In fact there wasn't a single machine in England capable of boring a cylinder with sufficient accuracy for his purpose. The problem was solved by hammering the cylinder to shape over a wooden mandrel.

When Watt finally tried a machine-bored cylinder, some four years later, he still needed rags, cork and an old felt hat as packing to keep all the steam from blowing past the piston before it could be harnessed.

It took John Wilkinson to devise a boring bar in 1774. Watt's partner described its performance, "Mr. Wilkinson has bored us several cylinders almost without error; that of 50 in. in diameter . . . does not err the thickness of an old shilling in any part."

Although standards had yet to be put to effective use Watt began to see their value—he coined the word "horsepower" which soon became an accepted standard before his death. Watt found by experiment how much weight a strong dray horse could lift—550 lb at a speed of 1 ft/sec.

Rainmakers

For as many years as rain has been falling on man's fields, he has tried in some fashion to control it. In early polytheistic societies, the most important gods were those of sun and rain. In later centuries, rain followed battles with such regularity, it was believed that noise of crashing swords and rattling sabers, from guns and cannon was the cause. In fact patents were issued during the late 1800s protecting the rights of inventors and their noisy "rainmaking machines." In the early 1890s the Department of Agriculture carried out a series of exhaustive tests to find if there really was a relationship between noise and rain. Results: negative.

Another idea was that large fires could bring storms and rain. Tribes set huge bonfires at night to signal the rain gods. If rain failed to fall the following day it simply meant the fire was either too small or the rain god was elsewhere that evening. A new fire would be started the next night, then the next, until rain fell—proving that the system worked.

The Smithsonian Institute

Ceremonial rain dances of the American Indian are well known, however, dancing wasn't the only string in their bows. They experimented with bloodletting, forced bathing, sprinkling of special persons with magic potions, smoking special types of tobacco. Some worked pretty well, too, if the timing was right.

In his book, *Life among the Indians*, George Catlin, recalls how one tribe, the Mandan, made it rain. ". . . In a very dry time, the medicine men assembled in the medicine lodge smoking and praying to the Great Spirit for rain, while a number of young men volunteered to make it rain. Each of these takes his turn to mount to the top of the wigwam at sunrise with his bow and arrow in his hand, talking to the clouds and asking for rain, or ranting and threatening the clouds with his bow, commanding it to rain. After several days of unsuccessful attempts some one more lucky than the rest happens to take his stand on a day on which a black cloud will be seen moving up. When he sees the rain actually falling he lets his arrows fly, and pointing says, 'There is now a hole in that cloud. We shall soon have rain enough.' When he comes down he is a medicine man. Those who have once succeeded in making it rain in the presence of the whole village, never undertake it a second time. They would rather give other young men a chance."

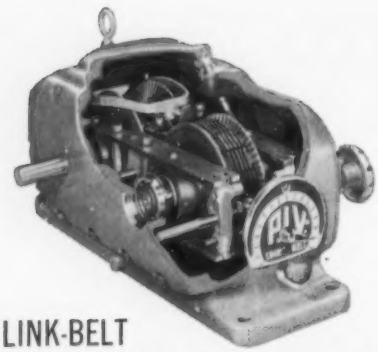
Now this generation is taking its turn—though somewhat more scientifically, as the story on p 106 points out. Yet vestiges of the past still remain. The second day of every February we watch the groundhog's shadow, and such sayings as: "The moon with a circle brings water in her beak" or "If the sun goes pale to bed/ 'twill rain tomorrow, it is said" are repeated and believed by many.

Sidelight

Tape recorders are getting to be America's favorite toy. Newspapers recently carried the story of a town plagued by starlings. The townspeople taped the calls of hawks and replayed them, loud, in the square. Good idea, but the starlings weren't fooled. Farmers in the midwest say taped music played during milking time increases milk output. And modern composers have also found the tape recorder an interesting tool. New, unusual sounds are made by taking a recorded sound and slowing it down or speeding it up. Music lovers are taking it seriously. A concert at Carnegie Hall this past season featured a tape recorder as a solo instrument.

The new Du Pont's Freon Products Division has gone one step further. At last month's Western Electronic Show they demonstrated a tape recorder that played while its hi-fi amplifier was immersed in a tank of liquid solvent. Now all they need is somebody who can dream up a suitable application.

—Benedict A Leerburger Jr.



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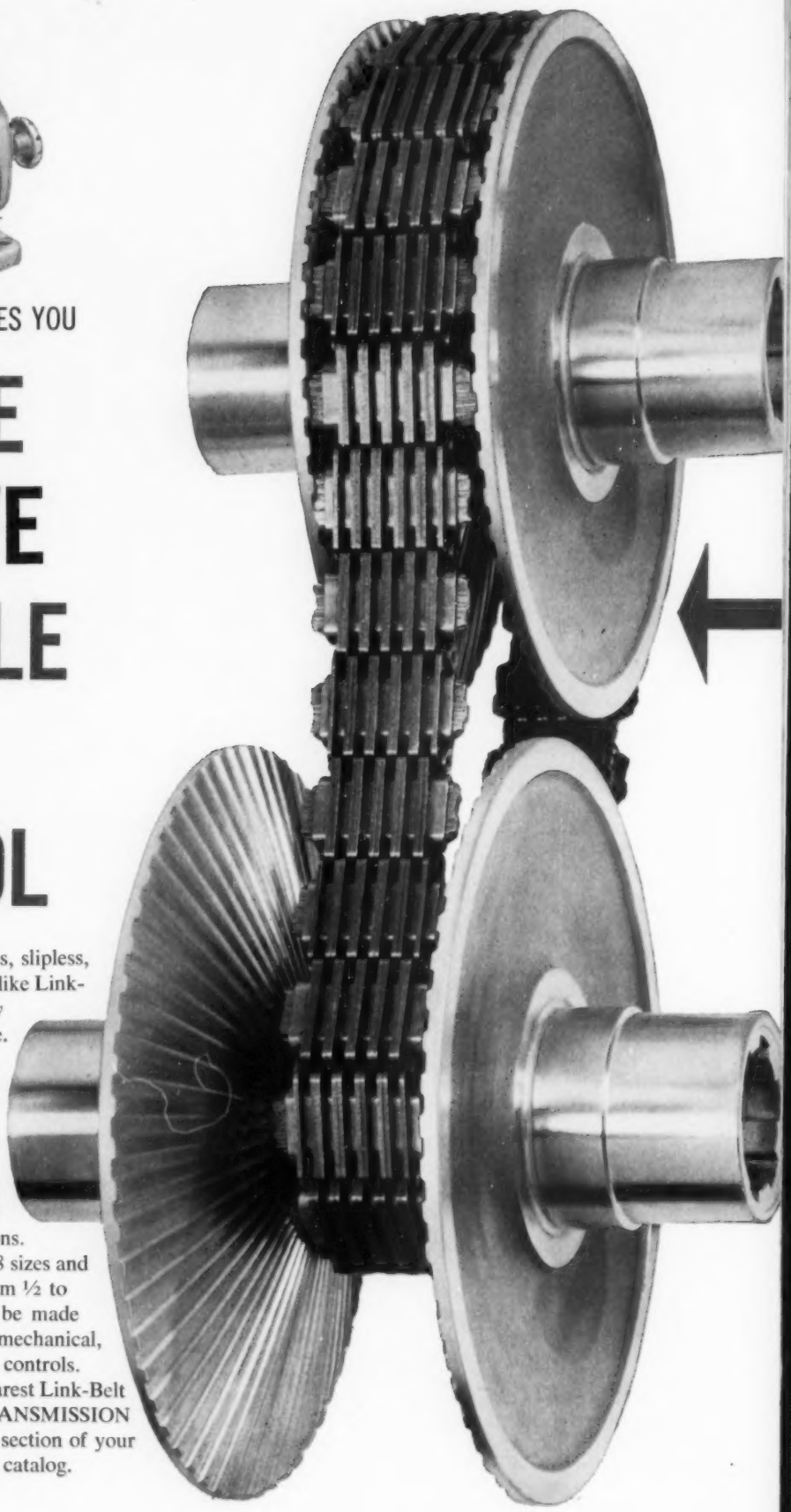

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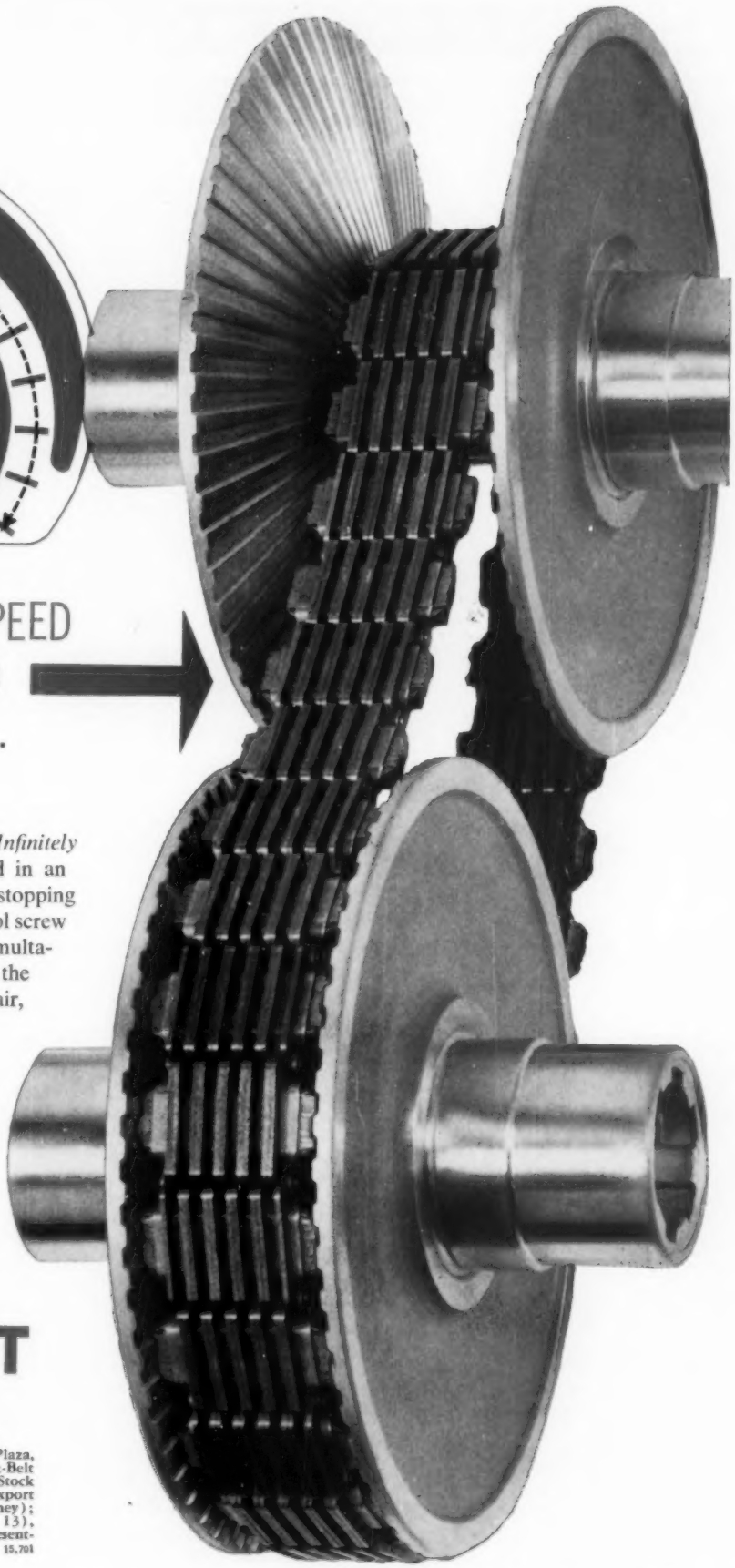

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With a Link-Belt P.I.V.—*Positive, Infinitely Variable*—drive, speeds can be varied in an instant, regardless of load and without stopping the driven machine. A turn of the control screw changes the speed. The control screw simultaneously varies the effective diameters of the conically shaped wheels—closing one pair, spreading the other. This automatically, *instantly* adjusts the chain to provide a controlled output speed. Slippage? Not a chance—P.I.V.'s chain-to-wheel grip is positive as a gear.

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Here's a new, fast, economy whiteprinter that fills a real need in small drafting rooms or large engineering departments.

Workprints for architects, consulting engineers, surveyors, contractors. The Rotolite Expeediter can handle *all* copying needs for the two- or three-man drafting operation, is always ready to cope with rush jobs, even after hours. With POST Super Vapo Papers, print production can be doubled.

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Recommended print materials. Use POST diazotype sensitized products —Vapo paper, sepia vellum, cloth or film—for best results. Get full information on Expeediter and standard Rotolite whiteprinters from your POST dealer or write Frederick Post Company, 3642 N. Avondale Avenue, Chicago 18, Ill.

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READER TO EDITOR

Lubrication system familiar

To the Editor:

The drawing of a new patented roller bearing lubrication system on page 14 of your August 7, 1961 issue interested me because I had seen the same system used for gear lubrication (under certain conditions). One particular design was used for vacuum-pumps in paper mills, which had water mixed with the air. The gears and impellers rotated in the required direction to discharge the water out the bottom of the pump. If the gears dipped into a simple sump, the oil soon overheated and caused serious trouble.

—JAMES B. CAHILL
Senior Design Engineer
General Dynamics/Astronautics

Saving ignition coil wear

To the Editor:

On reading the letter from Mr. W. P. West, "Save Ignition Coil Wear," (August 14, p 22), I would like to add that there is a new approach to the problem of ignition contact-breaker wear. A system has been developed using a power transistor as a high-speed relay in series with the primary of the ignition coil. In place of a contact breaker a small star wheel and magnetic pick-up are used. The pulses derived from the pick-up trigger the transistor, causing a heavy pulse of current in the coil to produce a hot spark at the plug.

The advantages are a hotter spark (up to twice the voltage from the old system at 5000 rpm), and no mechanical wear. Of course, spark advance can be arranged as before. Details of circuitry can be obtained from leading power-transistor manufacturers.

—W. JOHNS
Electronics Engineer

Psychic perceptronic recorder

To the Editor:

The poem in your August 14 issue in the "Reader to the Editor" column, p 22, entitled "Celestial Drawing Office" was of particular interest to us here at Hamilton. As a part of our

recent sales presentation, we prepared a rendering of the "Hamilton Psychic Perceptronic Recorder." Mr. George Ashton who contributed the poem to your publication requests in his last sentence that someone provide assistance in designing "the rest of the stuff" and we thought perhaps he might be interested in learning that someone has anticipated his request.

—W. W. HILLS
Sales Promotion Manager
Drafting Products
Hamilton Manufacturing Co
Two Rivers, Wis

COMING EVENTS

SEPTEMBER

20-21 . . . . Institute of Radio Engineers, AIEE and ISA, Industrial Electronics Symposium, Bradford Hotel, Boston

25-28 . . . . American Welding Society, Fall Meeting, Adolphus Hotel, Dallas, Texas

OCTOBER

9-11 . . . . Institute of Radio Engineers and AIEE, National Electronics Conference, International Amphitheater, Chicago

9-13 . . . . Society of Automotive Engineers, National Aeronautic Meeting, The Ambassador, Los Angeles

15-20 . . . . American Institute of Electrical Engineers, Fall General Meeting, Statler-Hilton Hotel, Detroit

17-19 . . . . American Society of Lubrication Engineers, and ASME, 8th Annual Lubrication Conference, Morrison Hotel, Chicago

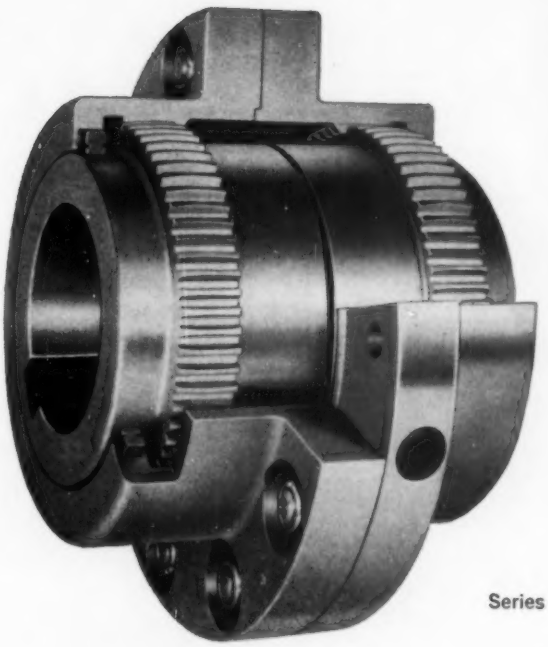
19-20 . . . . Illinois Institute of Technology and Armour Research Foundation, 1961 National Conference on Industrial Hydraulics, Sherman Hotel, Chicago

19-20 . . . . American Society for Quality Control, 16th Midwest Conference, Chase-Park Plaza Hotel, St. Louis

23-27 . . . . American Society for Metals, 43rd National Metal Congress, Cobo Hall, Detroit

24-26 . . . . Society of Automotive Engineers, National Transportation Meeting, Chase-Park Plaza, St. Louis, Mo

For a listing of addresses of societies and associations send 25¢ to Product Engineering Reader Service Dept, 330 W 42nd St, NY 36. Ask for brochure R 32.



Series "A"

Forged steel, lube-tight gear couplings

Both hubs and sleeves of these rugged Waldron standard "Series A" couplings are made of forged steel, and the two one-piece cover sleeves function as a single unit. There are no flexible parts to bend or break. At the same time, the grease-tight, patented Walflex seal is placed where the pressure is least, to prevent lubrication problems. You can get prompt delivery of any of the sizes listed below. Write for bulletin S-1000.

Size and nominal bore	Max. over bore	HP/100 rpm	Max. rpm
1¼A	1⅜	6	12,000
2A	2⅛	21	10,000
2½A	2⅝	45	9,000
3A	3⅜	87	7,500
3½A	3¾	150	6,500
4A	4¼	225	6,000
4½A	4¾	365	5,300
5A	5½	525	4,700
5½A	6	717	4,300
6A	6⅝	962	4,000
7A	7½	1137	3,300

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OIL SEALS
in Design Engineering

Garlock KLOZURE® Oil Seals stop oil leakage at bearings, increase efficiency of Denison Variable-Volume Hydraulic Pumps.

Denison designs hydraulic pumps around Garlock KLOZURE Oil Seals to assure maximum sealing efficiency.

Where pressures are too high for ordinary lip seals, KLOZURE Oil Seals prevent leakage of hydraulic oil and protect vital bearings as temperatures reach 150°F, pressures rise to 35 p.s.i., and shafts whirl at 1800 r.p.m. In use for the last twelve years, the seals have given complete satisfaction on the well-known line of axial piston and vane-type pumps made by Denison Engineering Division of American Brake Shoe Company.

Wherever bearings must have the best protection, Garlock KLOZURE Oil Seals are specified. On pumps like Denison . . . in steel mills . . . on power shovels and lift trucks . . . for motors, KLOZURE Oil Seals prevent leakage of lubrication, seal out harmful foreign matter. Whatever the application, there is KLOZURE Oil Seal to do the job. They are oil and grease resistant, impervious to mild acids and alkalies, non-abrasive, and will withstand temperatures from −40°F to +250°F. For extreme conditions, Garlock furnishes sealing elements resistant to practically any fluid, and serviceable as high as +500°F.

Availability is another prime reason for selecting Garlock KLOZURE Oil Seals. Once your design is finalized, you may select the proper seal from over 1800 stock items available from 180 national bearing distributors, including one near you.

It makes good sense to design with KLOZURE Oil Seals, as Denison and hundreds of other leading companies have found. See how you can benefit—call in your local Garlock representative. You will find him at the nearest of the 26 Garlock sales offices and warehouses throughout the U.S. and Canada. Or, write for Catalog AD-181. Garlock Inc., Palmyra, N. Y.

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first in silicones

Dow Corning

SILICONE NEWS

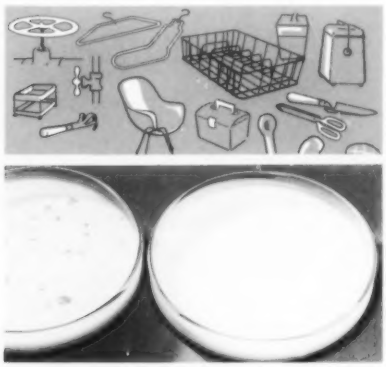
for design and development engineers • No. 86

New "Product Improvers"

Since silicones can improve the quality of many components you buy, it may pay to pass on your silicone savy to your suppliers. For example, silicone additives can make a big difference in the quality of plastisol coatings and polyurethane foams — two materials of considerable promise in the product design field. Here's how —

Plastisol Coatings—Is the coating uneven or wrinkled? Does it have pinholes or cavities? Weak spots allow moisture to penetrate . . . exude rust discoloration . . . eventually chip off or flake away to expose bare metal. Why tolerate this unnecessary problem when your supplier can eliminate it by including Dow Corning Silicones in his formulation?

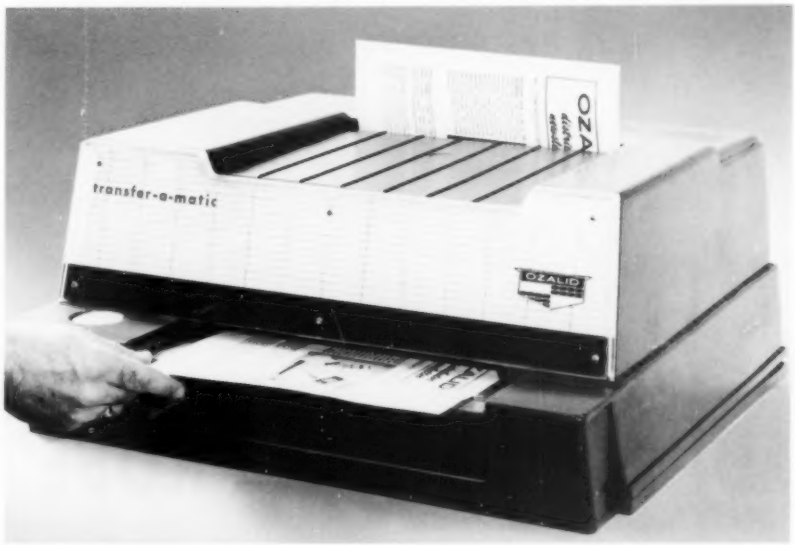
Silicones speed deaeration . . . prevent bubbles . . . cause plastisols to flow faster and more evenly. Silicones make possible thinner, lighter coatings free of cavities, pinholes and other weak spots. In many products such as furniture coverings and bushings, silicones give added "slip", improve mar and scuff resistance.



Both dishes were filled at the same time with the same plastisol solution, but a silicone additive was added to the solution before it was poured into dish at right. Note the absence of bubbles (entrapped air) in this dish.

Polyurethane Foams—Whether you use rigid or flexible foam — silicone additives can prove invaluable in helping your fabricator supply you with a high quality, low density foam that has uniform cell structure, time after time . . . that is free of partial fills, blowholes and other defects.

Your supplier will find Dow Corning silicone additives are economical, too, because lower concentrations — up *(Cont. Pg. 2)*



HASN'T STUCK YET!

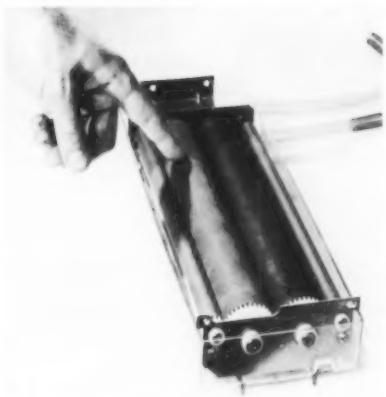
Q: "How to get stick-proof rubber rollers?"

A: "Make them of Silastic, the Dow Corning silicone rubber", according to design and development engineers in the Ozalid Division of General Aniline and Film Corporation.

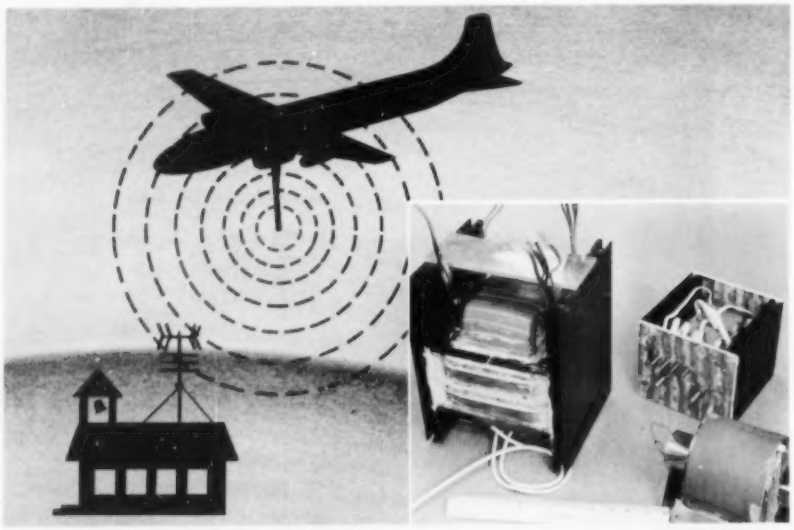
Ozalid produces the famous Transfer-a-matic copying machine for office and engineering use. During field tests of early prototype models, the sensitized side of copy paper sometimes stuck to the rubber rollers that squeeze off excess developer solution as the paper emerges from the bath. The result was torn paper or a jammed machine. The problem was especially acute after the rollers had dried during periods of idleness.

Here's how the Special Products Engineering Group at Ozalid described their solution: "On the recommendation of a Dow Corning sales engineer, we had some test rollers made of Silastic. After installing them on prototype models, we put the machines (and rollers) thru operational tests that were much more severe than actual service would be. The squeegee rollers made of Silastic came through with flying colors.

"The sensitized paper stripped off these rollers without the slightest hesitancy — under all conditions tested. What's more, neither the silicone rubber nor the developer solution reacted on each other. And no discoloration of paper has been noted. As a result, Silastic rollers are now standard equipment on all production model Transfer-a-matic machines."



Performance like this is typical of Silastic® the silicone rubber that remains resilient and tack-free despite exposure to many fluids, chemicals, steam, heat, cold, and weathering. For more information about Silastic and a list of rubber companies manufacturing parts made from this silicone rubber, circle . . . . . **No. 241**



EDUCATIONAL "PROBE"

Taped TV lectures will become standard classroom fare in hundreds of schools in six Midwest states as Fall semesters get underway. Their point of origin: two airborne DC-6's converted by Westinghouse engineers into powerful, aerial, transmitting centers.

From 23,000 feet, the DC-6's will send TV signals having an effective range of 150 to 300 miles — many times the 60 to 70 mile range of ground based transmitters. Another advantage, each aircraft is capable of transmitting more than one lecture simultaneously on each of two channels.

With educators looking hopefully over their shoulders, Westinghouse engineers have taken every precaution to assure the most reliable functioning of the complex telecast equipment. In this department, they've had a big assist from Dow Corning silicone insulation as a means of saving weight, reducing bulk and building a high reliability factor into power supplies.

Among the items of equipment insulated with Dow Corning Silicones are:

1. Rectifier Transformer. Three single phase transformers have been combined to produce a three-phase rectifier transformer rated at 35 KVA, 400 cycle, to supply the 16 KV high voltage output. Total weight of 3 transformers and mounts: 165 pounds.
2. Buck Boost Transformer. Three of these units are wired together to produce a three-phase transformer rated at 9 KVA. Total weight: 50 pounds.
3. Filter Choke. Two units with a rating of ½ henry at 3 amperes are used in the power supply. Total weight: 50 pounds.

All units are forced-air cooled and the weights given above include the weights of the cooling ducts.

Mr. Ray Lee, components design engineer for Westinghouse Air Arm, estimates the silicone insulated transformers weigh only half as much as they would if they were Class A insulated. They help appreciably in keeping down the total weight of the transmitting equipment . . . provide the ultimate in dependable operation. For more information explaining why it will pay you to investigate Dow Corning silicone insulation, circle . . . . ***No. 242***

Announcing New Customer Service

A new customer service facility has been established by Dow Corning to render complete and comprehensive engineering service to end users and fabricators of parts made from SILICONE MOLDING COMPOUNDS.

Dow Corning developed the first silicone molding compounds about 1948. Since then, our R&D people have produced several excellent materials, noted for their resistance to high and ultra-high temperatures. Thanks also to outstanding physical and electrical properties, these compounds have gained specification in a wide variety of commercial and military applications.

In recent years the performance demands placed on silicone molding compounds have become increasingly severe. To meet these more exacting requirements, we've turned more and more to custom compounding.

This, plus the obligation we have to fabricators to help them mold these custom compounds, led us to the establishment of the new ASG (Application Service Group) Molding Compound facility. For full information on Silicone Molding Compounds and the unique engineering service available from Dow Corning, circle . . . ***No. 243***

SILICONE ADDITIVES *(Cont.)*

to 25% less — produce consistently high quality foams with uniform cell structures.

Why not suggest these silicone "product improvers" to your suppliers? You'll get better components . . . produce better products. For more detailed information about silicone additives for plastisols, circle . . ***No. 244.*** For details about polyurethane additives, circle . . . . . ***No. 245***

Dow Corning Corporation, Dept. 5221, Midland, Michigan

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Preassembled! Prealigned!

Just bolt it down and wire it up!

This ready-to-install Warner "package drive" gives you a fractional hp clutch-brake unit assembled and ready to couple to an input and output shaft. Simply bolt it in place, hook up the lead wires and it is ready to go—*without* costly engineering or machining!

Rugged, reliable design

Lightweight and compact, the ELECTRO-PACK delivers high-cycle performance with rapid heat dissipation and freedom from maintenance. Sturdier, widespread, long-life bearings run cooler under all conditions.

Simple assembly, standard components

The ELECTRO-PACK incorporates *standard* Warner units, available all over the world. Service is simple, alignment fast and positive.

WARNER ELECTRIC

Get detailed specifications on this new Warner Electro-Pack Clutch-Brake Drive Package—fill in and mail coupon now.

WARNER ELECTRIC

Warner Electric Brake & Clutch Co., Dept. PE-9, Beloit, Wisconsin

I'm interested! Send me full details on the new Electro-Pack Clutch-Brake Drive.

Name_____

Title_____

Company_____

Address_____

City_____ Zone_____ State_____

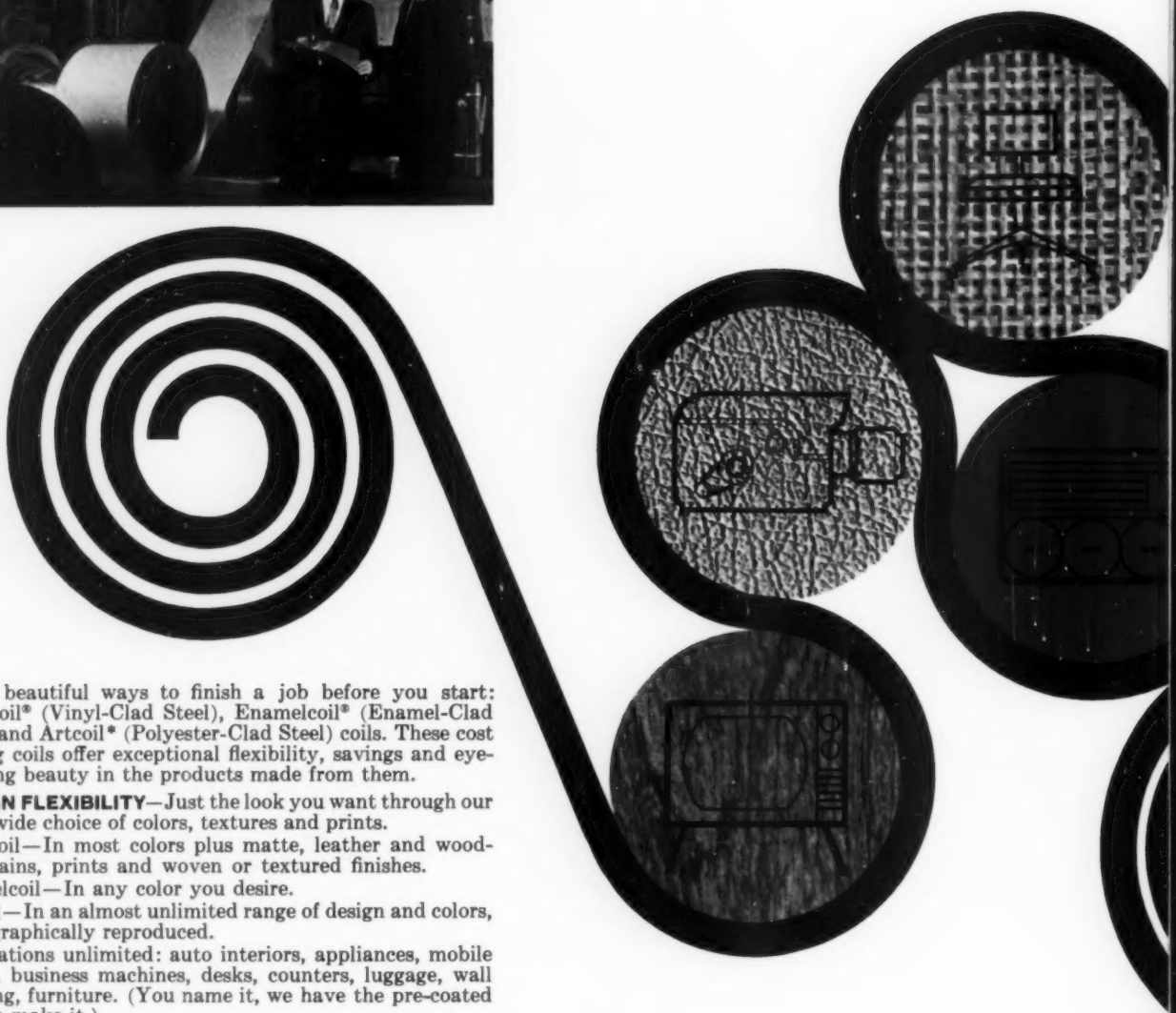
Stocked by Distributors in Principal Cities Throughout the World

CIRCLE 19 ON READER SERVICE CARD

CIRCLE 20 ON READER SERVICE CARD

A BEAUTIFUL FINISH TO START WITH ... AND SAVE WITH:

PRE-COATED STEEL COILS FROM ENAMELSTRIP



Three beautiful ways to finish a job before you start: Vinylcoil® (Vinyl-Clad Steel), Enamelcoil® (Enamel-Clad Steel) and Artcoil* (Polyester-Clad Steel) coils. These cost cutting coils offer exceptional flexibility, savings and eye-catching beauty in the products made from them.

DESIGN FLEXIBILITY—Just the look you want through our wide, wide choice of colors, textures and prints.

Vinylcoil—In most colors plus matte, leather and wood-like grains, prints and woven or textured finishes.

Enamelcoil—In any color you desire.

Artcoil—In an almost unlimited range of design and colors, photographically reproduced.

Applications unlimited: auto interiors, appliances, mobile homes, business machines, desks, counters, luggage, wall paneling, furniture. (You name it, we have the pre-coated steel to make it.)

PRODUCTION SAVINGS—No cleaning, tumbling, spraying, dipping, rustproofing, baking or drying. Less scrap loss; reduced investment in finishing equipment, space and labor requirements; lower insurance costs; longer die life. No fabricating restrictions—you can bend, crimp, drill, pierce, emboss, deep draw, roll form or lock seam most finishes—work them to the very limits of their tough steel base without damaging their durable coatings.

SALES APPEAL—Your product has immediate customer appeal because of its finished beauty, its resistance to scratches, scuff marks, stains and corrosion.

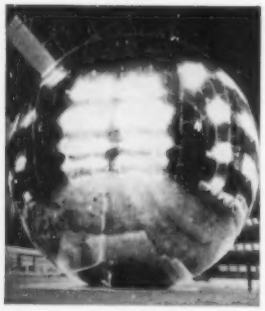
The competitive edge is yours when you start with a beautiful finish. Specify the good looks and long life—the savings and flexibility of these modern pre-coated steel coils from Enamelstrip. Contact your nearest National Steel Sales Office for complete details.

*Trademark

ENAMELSTRIP ALLENTOWN, PENNSYLVANIA

ENAMELSTRIP IS A DIVISION OF **NATIONAL STEEL CORPORATION**

Tough, durable Mylar® cuts costs... improves product performance



1. Huge (100 ft. diam.) inflatable satellite of metalized "Mylar" stays strong and flexible in sub-zero outer space.

2. Permanent collar stays of "Mylar" last the life of the shirt . . . keep their shape even after hundreds of launderings.

3. Capacitors with insulation of "Mylar" give long-lasting reliability . . . need for costly encapsulation is eliminated.

For example, "Mylar"* polyester film gives many products extra resistance to heat, cold and aging . . . lengthens their life. Today, "Mylar", with its resistance to chemicals and moisture, is improving the performance of products as different as surgical bandages and intercontinental ballistic missiles.

Can this unique plastic film and products made with it help you? For more information on "Mylar", write the Du Pont Co., Film Dept., Room S-8, Wilmington 98, Del.

DU PONT
REG. U.S. PAT. OFF.

*"Mylar" is Du Pont's registered trademark for its brand of polyester film.

Better Things for Better Living . . . *through Chemistry*

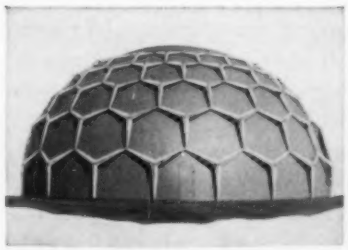
DU PONT MYLAR® POLYESTER FILM

What's News in Rubber...

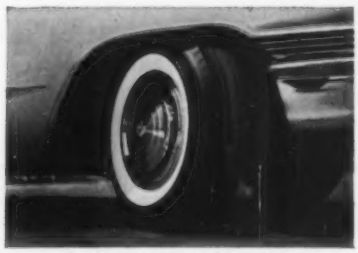
ENJAY BUTYL BEATS HEAT–WEATHER–WEAR

Continuous contact with materials as hot as 350°F (as in this conveyor belt) presents no problem to Enjay Butyl HT 10-66 when properly compounded for heat resistance. Actual service shows that other grades of Enjay Butyl also have exceptional resistance to high-temperature aging in ordinary atmospheres, oxygen or super-heated steam.

For application data, or for technical assistance in applying Butyl, write to Enjay, 15 West 51st Street, New York 19, New York.



Lightweight, durable, permanently flexible and applied cold, this colorful new roofing system at Longway Planetarium in Flint, Mich., takes full advantage of the unusual flexibility and non-hardening properties of Enjay Butyl.



New Enjay Butyl HT 10-66 adds toughness to air-holding innerliners which help assure correct inflation pressure on tubeless tires; gives greater blowout protection and improved tire-tread wear. Also used for sidewalls and chafer strips.

EXCITING NEW PRODUCTS THROUGH PETRO-CHEMISTRY

ENJAY CHEMICAL COMPANY

A DIVISION OF HUMBLE OIL & REFINING COMPANY

ENJAY

CIRCLE 23 ON READER SERVICE CARD

"We had 18-20 hours downtime every time we changed heats. With strip, we just hook on from heat to heat. No downtime."

"With strip we use smaller blanks to produce the same part."

"By using strip we save downtime, die repairs."

"Rejects have dropped from about 8% to less than 1%."

"We found we couldn't afford the low cost of sheet."

Read why Target Stamped Products, Inc., Kinsman, Ohio, switched from strip to sheet—and then back to strip. Comments are Harvey Haynam's, Target's president:

"We thought we'd give sheet a try back in 1958. The low cost looked too good to pass up. Today, you'd have a hard time finding a piece of cold rolled sheet around the shop.

"We were absorbing 18-20 hours of downtime every time we changed heats. With strip, we just hook on from heat to heat. The characteristics are the same from heat to heat and coil to coil. We don't waste time adjusting our dies.

"Strip saves us metal. We can use smaller blanks to produce the same part. I'd say we save from 1/16" to 3/32" of metal per part. That's a lot of steel when you're turning out 25-30 million parts a year.

"We don't have gauge problems now. The strip we buy is always rolled within our working tolerance. We work to a plus or minus .0025 inches.

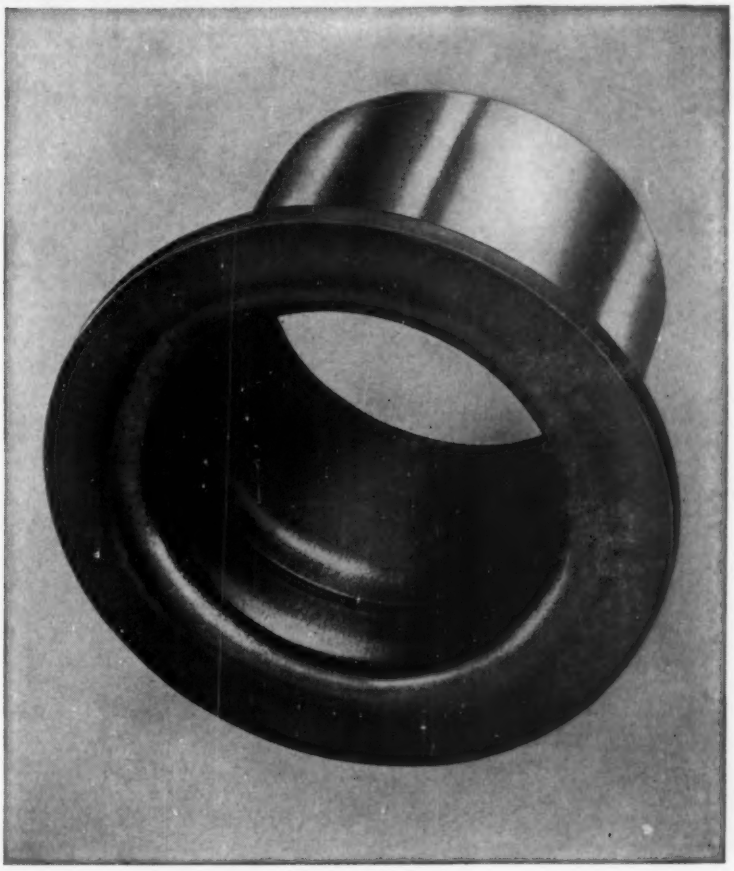
"So far, strip hasn't given us lamination troubles. It doesn't take much lamination to give you big trouble in a deep drawing operation. When the metal separates, part may stick to the punch while part stays in the cavity. As another blank transfers to the same station, there's a double smash and the die is ruined. That hasn't happened with strip. Saves a lot of downtime and die repair.

"Strip takes a deep draw without thinning out on you. Its uniform temper pays off when you're turning out Silent Blocks where both the ID and OD have to be right or the part's a reject.

"All in all our rejects have dropped from about 8% to less than 1% since we switched back to strip.

This mark tells you a product is made of modern, dependable Steel.

Outer metal bushing of a Silent Block. Target Stamped Products turns out millions of these each year for the auto industry. Silent Blocks are used in the suspension systems of all American cars—about eight to a car. To produce the piece, Target must work to a plus or minus .0025" tolerance or the Silent Block won't work. When Target switched back to strip, their rejects dropped from about 8% to less than 1%.



"You can have all the automation in the world, but if you're using the wrong steel, it just nickels and dimes you to death. With strip our machines keep working; we need less supervision, less tool repair. Our trim is small and our percentage of rejects is the smallest we've ever known. We found out we couldn't afford the low cost of sheet. That's why we're back with strip."

The switch is back to strip

Cold rolled sheet steel can be your best buy on a cost per pound basis. Certainly its quality has risen sharply since the war. But, pound cost is only part of the story. If you really need steel tailored to your specific production requirements, cold rolled strip is the answer.

Strip is not sold on an as-rolled basis. What you buy is a specific chemistry, temper, dimension, edge and finish to precisely meet your fabricating and end-use requirements.

American Steel and Wire has over 12,000 mill practices in available strip specifications. Many of your processing steps may actually be eliminated by using cold rolled strip.

Take a hard look at your production line and let our salesmen look with you. Check your rejects, your downtime, your scrap rate. Perhaps you can improve the quality of your product and cut production costs at the same time, with *tailored-to-the-job* cold rolled strip from American Steel and Wire. American Steel and Wire Division, Rockefeller Building, Cleveland 13, Ohio. USS and American are registered trademarks

USS **American Steel and Wire Division of United States Steel**

Columbia-Geneva Steel Division, San Francisco, Pacific Coast Distributors
Tennessee Coal and Iron Division, Fairfield, Ala., Southern Distributors
United States Steel Export Company, New York, Distributors Abroad

CIRCLE 26 ON READER SERVICE CARD→

FALK INTRODUCES 2 NEW SERIES OF VERSATILE SPEED REDUCERS

Designed to serve industry's current and future requirements

Type YB
Right Angle Horizontal
(write for Bulletin 2100)

Type Y Parallel Shaft
(write for Bulletin 1100)

Parallel Shaft and Right Angle Horizontal Reducers cataloged thru 1,570,000 lb-in. torque at low speed shaft ...larger units upon request. Ratios 1.84 thru 292 to 1 for parallel shaft; 5.06 thru 1207 to 1 for right angle horizontal

These new units are probably the most thoroughly engineered speed reducers on the market today. Final designs based upon years of development study and a background of 50 years experience make these units as dependable as the name "FALK". A few of their many features are...

PINPOINT APPLICATION COVERAGE Wide choice of sizes and ratios permits the most economical selection of a correctly rated unit for each application. In each series of parallel shaft and right angle reducers, cataloged sizes range up to 1,570,000 lb-in. torque at the (11 inch dia.) low speed shaft. (Other standard designs to 25,000,000 lb-in. torque; custom designs for higher capacities.)

UNMATCHED VERSATILITY The "Basic Y" speed reducer design permits economical modification to meet a multitude of specific requirements. Smooth, flat surfaces simplify mounting of motor brackets, backstops, brakes, and any number of other accessories.

RUGGED HOUSINGS Sturdy housings not only provide maximum rigidity to maintain proper alignment of gearing, but also have the strength to support heavy overhung loads and withstand accidental blows.

DEPENDABLE FALK GEARING Gears are selected with the proper proportions and hardness to provide the optimum combination of maximum durability and strength for high shock as well as uniform loads.

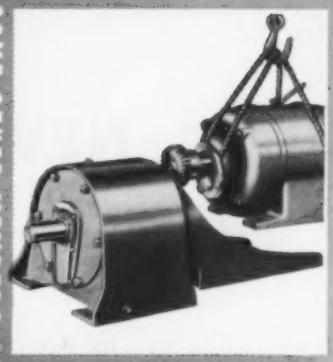
BEARINGS TO SUIT THE OVERHUNG LOAD Standard reducers can meet custom-built requirements with optional stock bearings and shafts (at only a nominal extra charge.) Maximum overhung load capacities are so great that for some conditions, still within the capacity of the reducer, extra strong supporting foundations and bolts must be provided.

DOUBLE GEAR LIFE Standard double ended shafts can be reversed end for end to bring into contact the unused surfaces of the gear teeth for twice the normal gear life.

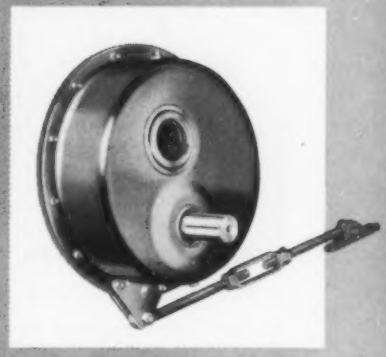
SEALS FOR ALL CONDITIONS Standard equipment oil seals assure oil-tight and dirt-free gear units for normal applications. Standard abrasive and moisture-resistant seals available upon order.

THE FALK CORPORATION, MILWAUKEE 1, WISCONSIN
MANUFACTURERS OF QUALITY GEAR DRIVES AND FLEXIBLE SHAFT COUPLINGS
Representatives and Distributors in most principal cities

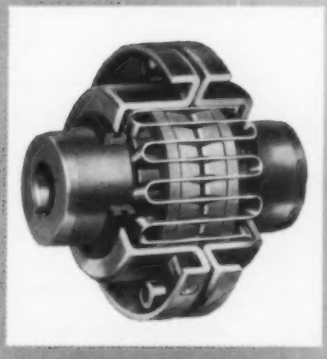
SOME OTHER MEMBERS OF AMERICA'S FIRST FAMILY OF POWER TRANSMISSION PRODUCTS



ALL-MOTOR MOTOREDUCERS



SHAFT MOUNTED DRIVES



STEELFLEX COUPLINGS

FALK

A GOOD NAME IN INDUSTRY

FALK, ALL-MOTOR, and STEELFLEX are registered trademarks

From Monsanto FluiDesign Service...

NEW "BLOOD" FOR ELECTRONIC

Coolants for computers... designed inside the circuit!

Pinpointed heat control will be more critical than ever in tomorrow's big computers—to assure *reliability* for the new jobs they'll be called upon to perform. Today, an "air conditioned" room, or perhaps forced-air cooling, keeps temperature of circuits within bounds. But tomorrow's transistorized, *unattended* computers will service oil refining, chemical processing, production lines, radar interpretation—in environments from scorching desert to arctic blizzard. *Safeguard* these "big job" circuits with *packaged* fluid dielectric/coolants—instead of bulky convection cooling or cumbersome forced-air systems. Precise heat control with fluids can make your equipment more reliable—more salable—can help qualify electronic equipment for many new tasks.

MONSANTO FLUIDESIGN SERVICE OFFERS YOU:

1. Sophisticated application experience with fluids
2. Years-ahead research on new types of fluids
3. Time-saving facilities for testing new uses
4. More *job-proven* functional fluids than any other manufacturer in the world
5. Design-oriented *know-how* to help you develop more compact, safer, and more reliable equipment

TYPICAL PROPERTIES OF A FEW MONSANTO FLUIDS	OPERATING TEMPERATURE RANGE (°F)	VISCOSITY (Centistokes @ °F)	POUR POINT (°F)	MAXIMUM LONG TERM BULK TEMPERATURE (°F)	FLASH POINT (°F)
COOLANOL® 35	<−120 to >350	934 @ −65 6.5 @ 100 2.2 @ 210	<−120	350	370
COOLANOL 45	<−85 to >400	2400 @ −65 12.2 @ 100 3.95 @ 210	<−85	400	370
OS-59	−65 to 600	1380 @ −65 6.8 @ 100 2.2 @ 210	<−85	500	370
OS-124*	+40 to 900	363 @ 100 13.1 @ 210	+40	800	550
AROCLOR® 1242	+40 to 600	17.2 @ 100 2.5 @ 210	+2	600	fire resistant...
OS-80	(Preservative Fluid—*non-operational*				
MONOISOPROPYL BIPHENYL*	−40 to 650	75 @ 0 4.6 @ 100 1.42 @ 210	−65	650	315

*RADIATION RESISTANT

THESE COOLANTS ARE AVAILABLE NOW AND MANY OTHERS

BRAINS AND RADAR EYES

Heat control to defy the arctic or tropics!

If you are designing radar "eyes" to operate intelligence networks ranging from the frigid top of the world to the steaming tropics, you'll want to check with Monsanto about coolant fluids that operate reliably from below *minus* 80° F. to over 500° F. These fluids are chemically stable; won't freeze or sludge; do not corrode circulating pumps or the vital "veins" of high-power klystrons, magnetrons, traveling wave, or tropospheric scatter installations. Do you want the *maximum* reliability of pinpoint temperature control—with a *minimum* of mechanical and maintenance problems with the coolant? Monsanto fluids can help you reduce system complexity—while increasing system reliability.

BE SURE TO GET YOUR FACT-PACKED FLUIDESIGN FILE. WRITE ON YOUR LETTERHEAD TO:

Monsanto

Monsanto Chemical Company
Organic Chemicals Division
FluiDesign Service, Dept. 4452B
St. Louis 66, Missouri

	FIRE POINT (°F)	COEFFICIENT OF THERMAL EXPANSION (per °F)	SPECIFIC GRAVITY @ 25°/25°C or M. Pt.	SPECIFIC HEAT @ 25°C or M. Pt. BTU/lb/°F	THERMAL CONDUCTIVITY BTU/hr/ft²/ft/°F
	430	**0.00047**	**0.89**	**0.45**	**0.079**
	430	**0.00048**	**0.89**	**0.45**	**0.080**
	435	**0.00046**	**0.88**	**0.45**	**0.077**
	660	**0.00033**	**1.204**	**0.365**	**0.075**
	does not support combustion	**0.00038**	**1.38**	**0.29**	**0.058**
***product*—protects systems in storage)**					
	340	**0.00045**	**1.00**	**0.40**	**0.070**

ARE UNDER DEVELOPMENT FROM NEW BASE STOCKS

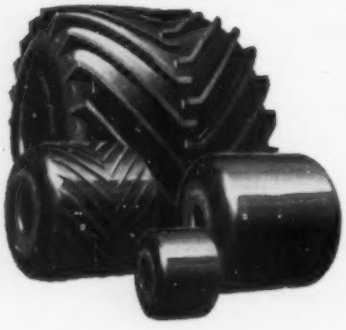
Terra-Tires solved problems on this equipment— How can they help you in your design?

Problem: MOBILITY
Solution: Terra-Tires by Goodyear. Their wide tread, low inflation pressures and high flotation let this truck, owned by Shell Oil Company, easily pull free of a deep bog during an oil exploration.

Problem: FLOTATION
Solution: Terra-Tires by Goodyear. An Indiana company put Terra-Tires on this scraper to prevent delays caused by equipment miring down. Result: Faster peat harvesting at lower cost.

Problem: NON-COMPACTION
Solution: Terra-Tires by Goodyear. A racetrack that's uneven can damage thoroughbreds' legs, so Santa Anita uses tractors with Terra-Tires to condition track after a rain without compacting ground.

Problem: CARGO PROTECTION
Solution: Terra-Tires by Goodyear. Bananas bruise easily, so United Fruit "floats" its fruit from farm to railhead on equipment fitted with Terra-Tires, which also permit all-season hauling.



If you're designing a "go-anywhere" vehicle – or one that must baby its cargo or the ground it goes on–Terra-Tires by Goodyear should be a part of your design. They're available in a wide range of sizes and treads. Let us know what you're driving at—or on—or over, we'll be glad to suggest a design to solve your problem. Write Goodyear, Aviation Products Division, Dept. I-1720, Akron 16, Ohio, or Los Angeles 54, California.

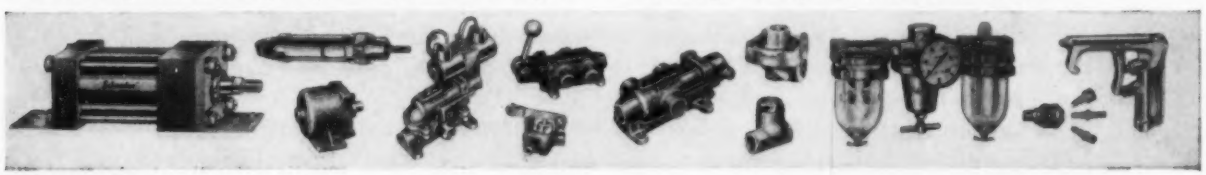
Lots of good things come from **GOODYEAR**

Terra-Tire–T.M. The Goodyear Tire & Rubber Company, Akron, Ohio

EXAMPLE: Schrader Square-end Cylinders not only have quality built into every part, but feature many extras. For instance, the unique cartridge-type bronze bearing assembly (A) is easily removed by releasing just one retaining ring—no need to dismantle the entire cylinder for bearing maintenance. Special "step" design cylinder seal (B) assures perfect alignment and positive seal without danger of gasket damage. Below surface cushion adjusting screws (C) are protected from damage but fully accessible. They lock to eliminate loosening due to vibration.

Interchangeable with all JIC cylinders, Schrader also provides a variety of mountings. Special bushings are available for bone-dry piston rod in hydraulic operation.

ANOTHER EXAMPLE: Schrader's new direct action Hydraulic Gauges without mechanical linkage (A) eliminate fatigue failure of internal parts. They can withstand 100% overload without damage to accuracy, and are triple-damped (B) to eliminate indicator oscillation from pump pulses, surges, or shock that would damage other types. Can be maintained and calibrated easily in the field. PSI pressure ranges 0-500, -1500, -3000, and -5000.



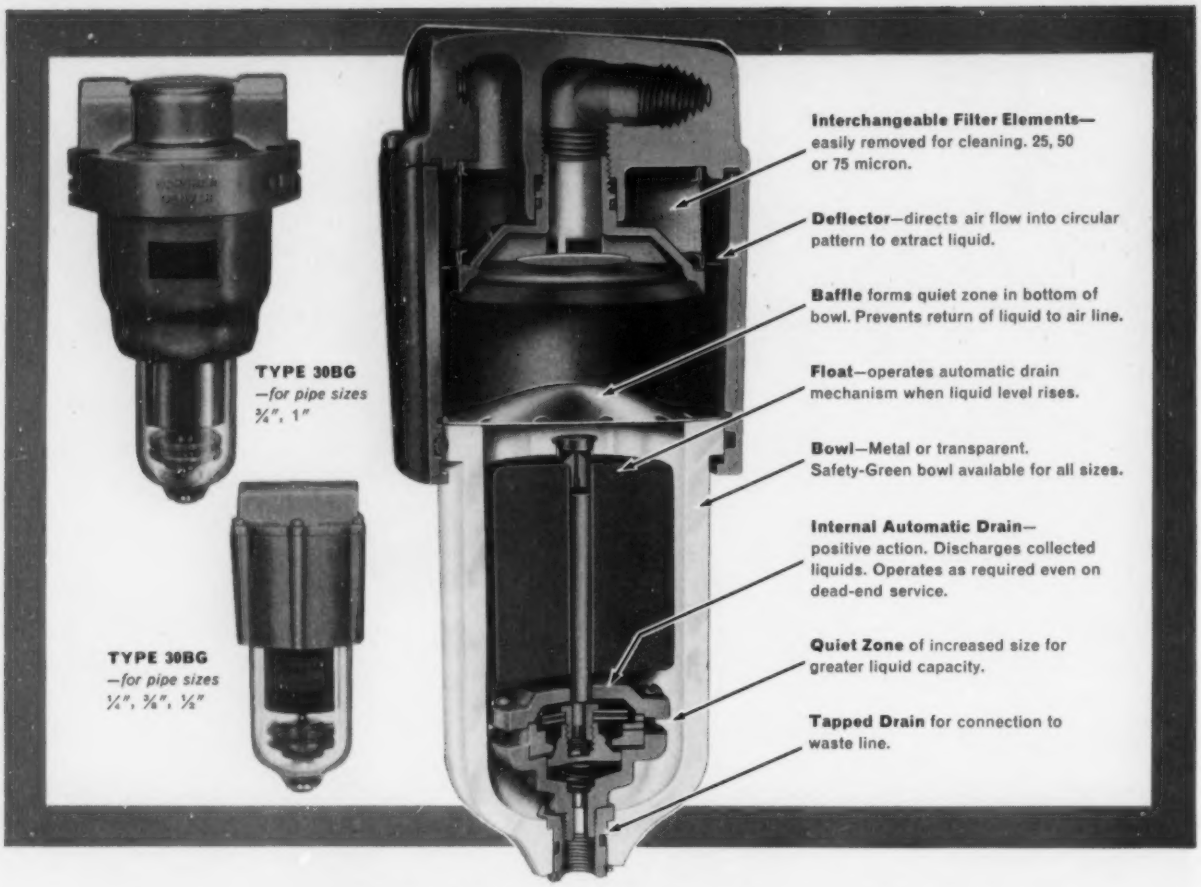
This new Schrader catalog is available at your Schrader distributor, who is stocked with the complete range of sizes and types of Schrader air circuitry products. Consult the Yellow Pages or write Schrader.

FULL LINES OF QUALITY AIR CIRCUIT COMPONENTS • OFF-THE-SHELF SERVICE AND INFORMATION FROM YOUR NEARBY DISTRIBUTOR • STAFFED WITH AIR CIRCUIT EXPERTS • CONSULT YELLOW PAGES OR WRITE FOR HIS ADDRESS

Schrader®
a division of **SCOVILL**

A. SCHRADER'S SON
Division of Scovill Manufacturing Co., Inc.
47 Vanderbilt Ave., Brooklyn 38, N. Y.

QUALITY AIR CONTROL PRODUCTS


TYPE 30BG
—for pipe sizes
¾", 1"
TYPE 30BG
—for pipe sizes
¼", ⅜", ½"
Interchangeable Filter Elements—easily removed for cleaning. 25, 50 or 75 micron.
Deflector—directs air flow into circular pattern to extract liquid.
Baffle forms quiet zone in bottom of bowl. Prevents return of liquid to air line.
Float—operates automatic drain mechanism when liquid level rises.
Bowl—Metal or transparent. Safety-Green bowl available for all sizes.
Internal Automatic Drain—positive action. Discharges collected liquids. Operates as required even on dead-end service.
Quiet Zone of increased size for greater liquid capacity.
Tapped Drain for connection to waste line.

Norgren Automatic-Drain Compressed-Air-Line Filters provide FULL-TIME protection

The purpose of a compressed-air-line filter is to remove liquids and solids from the air-stream so that they cannot clog, corrode or damage air-powered equipment. Your equipment needs this protection *full-time.*

Manual drain filters are often neglected . . . are not drained as often as they should be. When excess liquid collects in the bowl these filters no longer do the job. Liquid in the air-stream passes right on through to your air tools, cylinders and other air-operated equipment.

This cannot happen with Norgren Automatic-Drain Filters. They empty themselves as often as required . . . never get too full. Operation is determined entirely by the need for draining; and not, as with some makes, by changes in air pressure. Although an automatic-drain filter costs more than a manual drain filter, Norgren Automatic-Drain filters protect your air-powered equipment *full-time* day and night, year-in-year-out. They prevent costly wear and damage to your equipment and eliminate man-hour costs for manual draining.

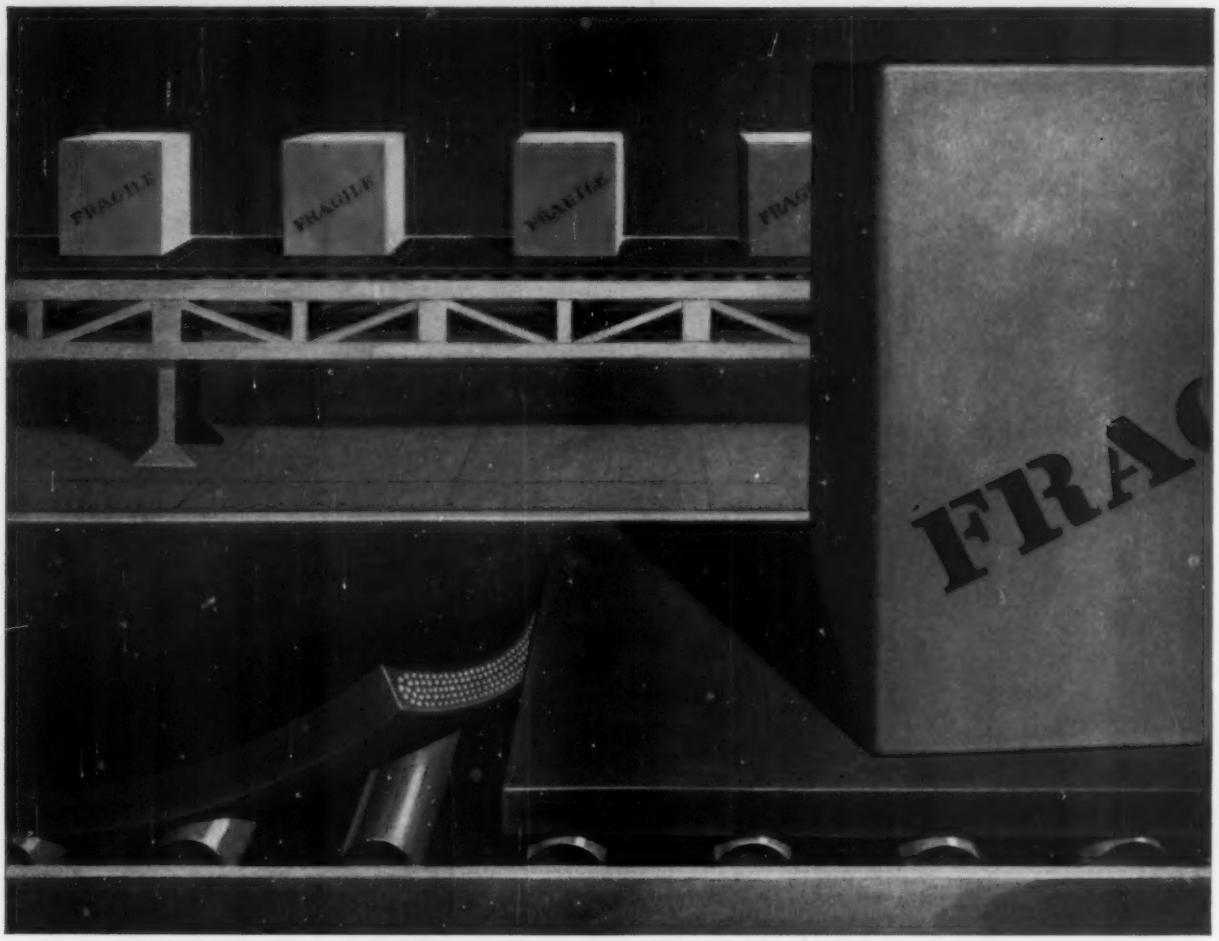
Order Norgren Automatic-Drain Filters from your nearby Norgren Representative, listed in the telephone directory—or write factory for catalog.

FOUNDED IN 1925

C. A. NORGREN CO.

3428 SOUTH ELATI STREET, ENGLEWOOD, COLORADO

An example of Avisco Rayons in Industry



For stronger, lighter-weight belting, reinforce with Avisco® XL-I rayon fabrics

There are compelling reasons for using Avisco XL-I rayon fibers in your belting fabrics. To begin with, they give you lighter, stronger belts *and for less money* than heavier cotton belting duck—up to 60% greater conditioned tensile ounce-for-ounce.

Avisco XL-I rayon constructions also have excellent flexibility which means good troughing and conformability, 3 to 5 times the fatigue life of cotton. Greater resistance to impact enables belts with rayon to absorb starting and shock loads easily. Lightweight rayon requires less power for starting and running. Send for engineering data on Avisco XL-I rayon fiber.

QUICK REPLY COUPON 13-6

Industrial Merchandising Division
American Viscose Corporation
350 Fifth Avenue, New York 1, N.Y.

Please contact me about Avisco XL-I rayon for use in the following application:_____

Name_____

Company_____

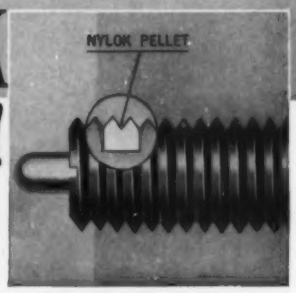
Address_____

City_____ Zone____ State_____

AVISCO RAYON

AMERICAN VISCOSE CORPORATION, 350 Fifth Avenue, New York 1, N.Y.

NOW all VLIER Spring Plungers are available with NYLOK at no extra cost!



Nylok-fitted bodies are self-locking; eliminate need for checknuts or other secondary locking devices.

Whether you use Vlier Spring Plungers on tooling, or for original equipment applications, you'll like this new self-locking feature.

Each Vlier Spring Plunger body is permanently fitted with a tough, resilient nylon pellet which slightly protrudes above the major thread diameter. As the plunger is inserted in the tapped hole, this pellet is *compressed* (not cut), exerting a spring-like pressure on one side of the plunger body. This *constant* lateral thrust wedges the mating threads together, assuring a *positive* lock that remains vibration-proof regardless of cyclic loads.

PERFECT FOR USE WHERE PERIODIC ADJUSTMENTS MUST BE MADE—The self-locking feature is effective whether the body is seated or not, permitting the Vlier Spring Plunger to be easily and accurately adjusted as required... cannot back off or be shaken loose once set.

RE-USEABLE MANY TIMES—When the Vlier Spring Plunger is removed, the Nylok pellet strives to return to its original shape. Parts can be used numerous times before any locking pressure is lost.

NO EXTRA COST FOR SELF-LOCKING FEATURE—All standard Vlier Spring Plungers are now available with the self-locking feature at no increase in price! However, all models may still be ordered without Nylok.

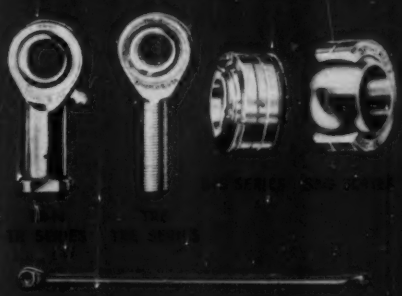
Your Vlier distributor now has Nylok-fitted Vlier Spring Plungers on his shelf. Order a supply today.

VLIER
Engineering Corporation
A subsidiary of Barry Wright Corporation
8900 Santa Monica Blvd., Los Angeles 46, California

SEALMASTER®

Two products... one standard of quality!

SPHERCO®
SPHERICAL BEARINGS & ROD ENDS



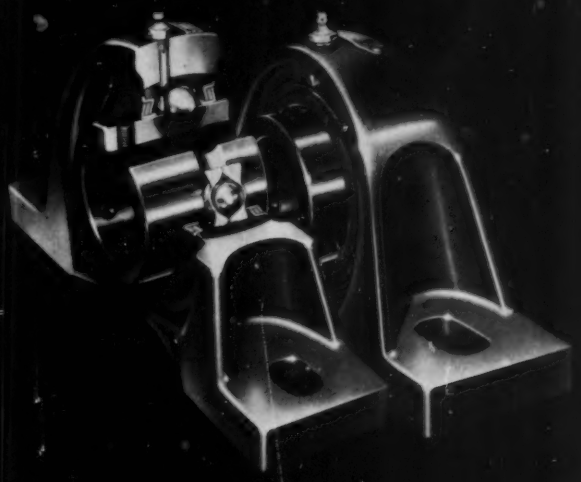
If you have an application involving the transfer of motion, Spherco bearings can provide your needs in a wide range of designs, bore diameters, thread sizes and materials to meet all applications.

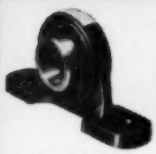
WRITE FOR BULLETIN 257

SEALMASTER
SEALMASTER BEARINGS

STEPHENS-ADAMSON MFG. CO.

SEALMASTER®
BALL BEARING UNITS



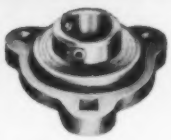


LP PILLOW BLOCK

L BEARING

SL BEARING

LFT FLANGE UNIT



LF FLANGE UNIT

Normal-Standard Medium Duty PILLOW BLOCKS

Standard Medium Duty FLANGE UNITS

FLANGE CARTRIDGE UNIT

TAKE-UP UNIT

TWO BOLT FLANGE UNIT

Sealmaster bearings offer a complete line of mounted units to meet every requirement. This line offers the ultimate in quality and performance at the most economical level.

WRITE TODAY FOR SEALMASTER CATALOG 454

CIRCLE 35 ON READER SERVICE CARD

FOR HIGH-TEMPERATURE, HIGH-PRESSURE APPLICATION...

NEW 2 AND 3-WAY CECO VALVES ARE READILY ADAPTABLE TO YOUR REQUIREMENTS!

Fabricated without organic materials, the carbon steel valves pictured here represent a new Chandler Evans valve design which lends itself to a variety of special-purpose applications.

Requirements on this particular assignment were for valves to provide flow of demineralized water up to 400 gpm at temperatures to 600°F. and pressures to 2000 psig, with minimum maintenance for 25-year service. An air-operated actuator is an integral part of each assembly, and an air-supply system and remote control panel complete the package.

Development of valves in this series was facilitated by CECO's high-temperature test loop. CECO engineers accented flexibility in design. The valves can be scaled up or down to suit other flow, temperature or pressure requirements. They can be fabricated from materials compatible with corrosive fluids. They are ideal for remote control installation, using manually or electrically operated selector valves. Pneumatically actuated in present form, they can be adapted for mechanical, hydraulic or electrical actuation.

To discuss your requirements, contact Mr. Harold E. Francis, Nuclear and Industrial Products Manager.

CHANDLER EVANS CORPORATION West Hartford 1, Connecticut

A SUBSIDIARY OF FAIRBANKS WHITNEY CORP.

CECO SYSTEMS CONTROLS

DOUBLE the Poles in the Same Space

NEW Square D 2-pole Limit Switch

9007 AW Limit Switch with 2-pole snap switch

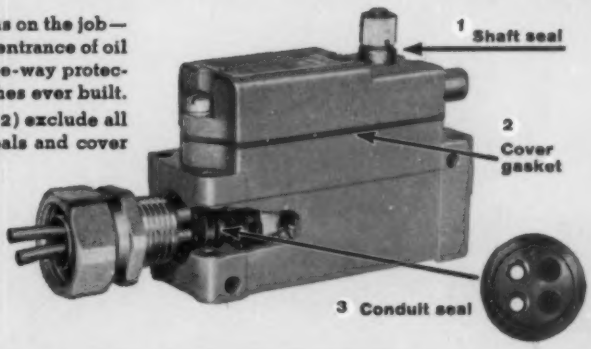
CUTS COSTS— IS THE MOST COMPACT

- One device can do the job of two —eliminate second limit switch or relay
- Control 4 circuits with 2-pole double-throw switch
- Cuts installation time
- Most compact of any 2-pole switch
- Saves mounting space
- Mounts interchangeably with other 9007 AW limit switches
- Simplifies circuitry—and simplified circuitry means greater dependability

THE COMPLETE ANSWER TO LIMIT SWITCH OIL-TIGHTNESS!

The real test of a limit switch is how it performs on the job—and the most common cause of trouble is the entrance of oil or coolant. Square D limit switches have three-way protection that makes them the most oil-tight switches ever built.

An effective shaft seal (1) and cover gasket (2) exclude all oils and coolants. However, even the best seals and cover gaskets cannot prevent entrance of condensation and leakage into the switch through the conduit system. Square D has solved this problem with a new and inexpensive optional conduit seal (3) which fits the conduit entrance of AW and T limit switches, and completely excludes all liquids.



Get the Complete Story! *Write Square D Company, Dept. SA, 4041 North Richards Street, Milwaukee 12, Wisconsin*

SQUARE D COMPANY

wherever electricity is distributed and controlled

IN A MANHOLE OR ON A MIXER

Wagner® "Stand-up" motors pack plenty of power

Here's plenty of power for equipment requiring normal thrust vertically mounted motors. Wagner® Vertical Solid Shaft Motors provide power without problems for your pumps, mixers, agitators, axial fans, centrifuges, presses . . . anywhere you need a vertical motor drive with plenty of stamina.

Wagner Vertical Solid Shaft Motors are end-mounted, squirrel-cage type with a NEMA Type "P" base that is precision-machined to mate with equipment. Smooth running under cyclic loads, they won't labor or stall . . . conform with NEMA Design B motor requirements in all respects. Their cast iron construction is simple and rugged . . . stands off corrosion . . . stands up to rough, tough treatment. Here are motors that are designed to give you economical, maintenance-free service the year 'round, indoors or out.

Wagner "Stand-up" Motors are available in ratings of 1 hp and larger with nominal full load speeds of 3500, 1750, 1160, or 870 rpm, and can be supplied with a completely dripproof enclosure, a standard totally enclosed fan-cooled enclosure, or an explosion-proof TEFC enclosure. Whatever the horsepower, whatever the enclosure, whatever the application, one thing is sure . . . these compact, power packages get the job done. For all the reasons why, check with the Wagner Sales Engineer in the Wagner branch nearest you, or write us for Bulletin MU-249.

Branches and Distributors in all Principal Cities

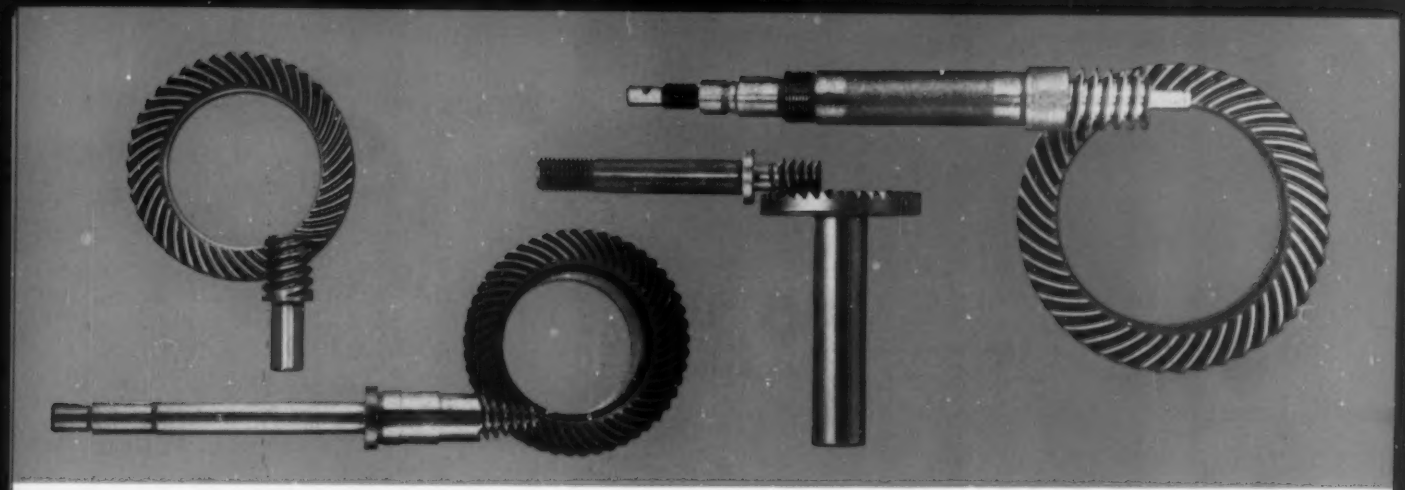
Wagner Electric Corporation

6406 PLYMOUTH AVENUE, ST. LOUIS 33, MO., U.S.A.

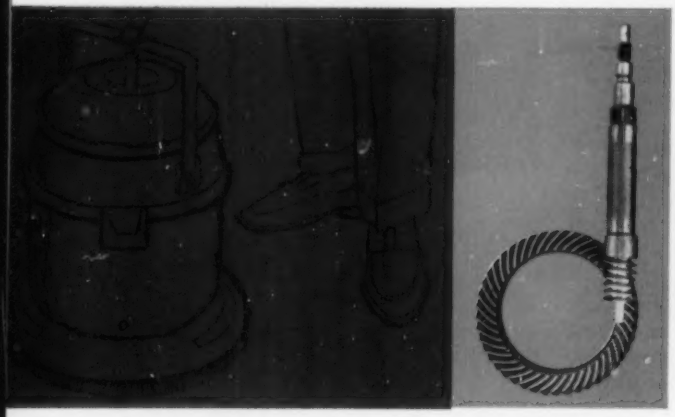
Manufacturers of LOCKHEED® Products

Wagner Vertical Solid Shaft Motors provide the power for Smith & Loveless sewage pumping stations.

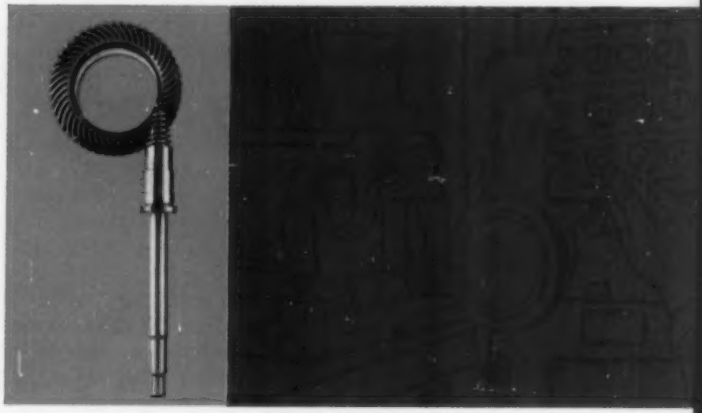
WH61-8



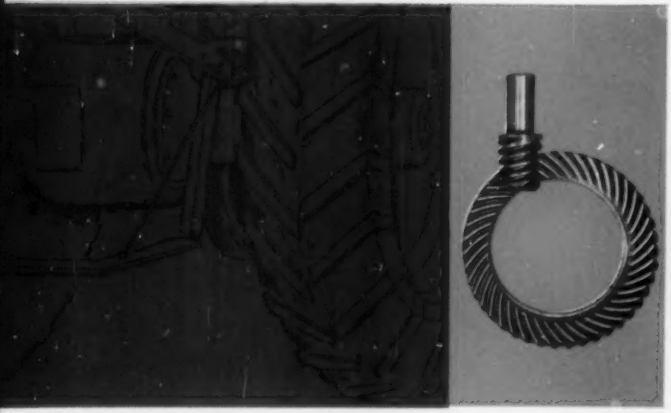
WHICH OF THESE HIGH-RATIO HYPOIDS IS "**JUST RIGHT**" FOR YOUR PRODUCT?



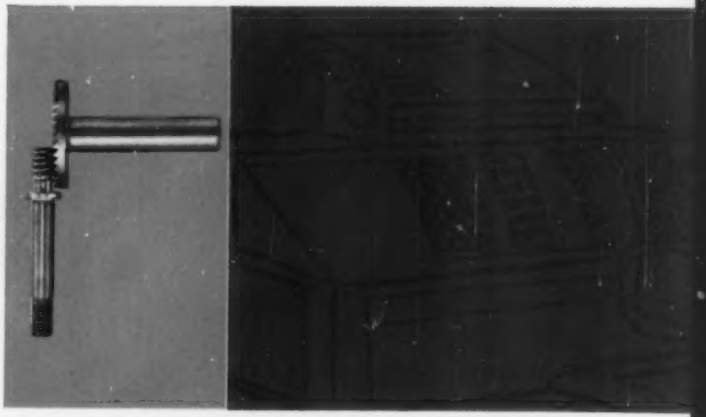
For hand tools. Where space is a problem—as in portable tools like this one—the high offset lets you design a more compact unit. Choose just the offset to solve your design problem with a more flexible, more compact unit than the corresponding worm and wheel.



. . . or machine tools. This high-offset pair lets you combine high reduction with strength, compactness and other advantages you might find profitable in designing machine tools. High-ratio hypoids can be produced on Gleason equipment for ratios of 1:10, 1:40 or even higher.



Big and strong. Where you need strength—as in farm machinery—high-offset hypoid pinions (with teeth which tend to "wrap around") are larger and stronger than corresponding bevel pinions. An extended shank on cylindrical pinions makes very rigid straddle mountings practical.



. . . or small and smooth. For smooth operation—as in office equipment that must run quietly—high-offset pairs provide smooth, quiet tooth action. Because teeth "wrap around" the pinion, you get continuous action—even with just one or two teeth! Grinders are available for applications requiring precision finish.

High-offset or high-ratio hypoids can be cut, tested, and quenched on the same Gleason equipment that is used on more familiar spiral bevel and hypoid gears. You can get more information about Gleason high-ratio hypoid gears by writing for free literature. Submit your prints for recommendations.

GLEASON WORKS

1000 UNIVERSITY AVE., ROCHESTER 3, N.Y.

CIRCLE 39 ON READER SERVICE CARD

Here Your Motor Starter Dollar Buys

MORE OF THE QUALITIES YOU NEED

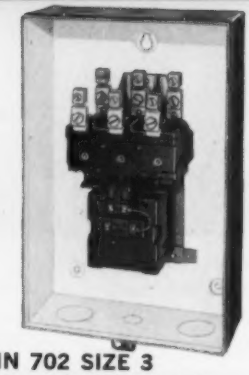
BULLETIN 709 SIZE 3
across-the-line solenoid starter in Nema Type 1 enclosure.

Where else could you possibly obtain—in one complete line—all of the desirable features of the ideal motor control...

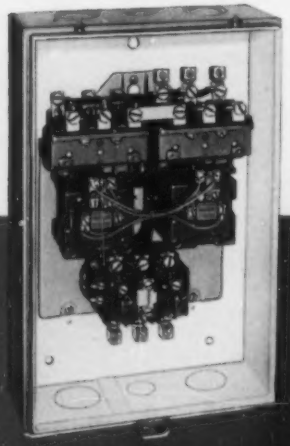
1. **Smaller size**
2. **Greater reliability**
3. **Remarkable switching capacity**
4. **Longer life**
5. **Conscientious overload protection**
6. **Simpler installation**
7. **Complete accessibility**
8. **Beautiful appearance—either open or enclosed**
9. **Surprising light weight**

The heart of this new line of magnetic motor starters is the unique solenoid contactor. While it retains the famous A-B one-moving-part principle, it is completely new and far more efficient. This fact is reflected in reduced dimensions for all of these controls. Yet, this contactor design will perform reliably for many more *millions* of trouble free operations.

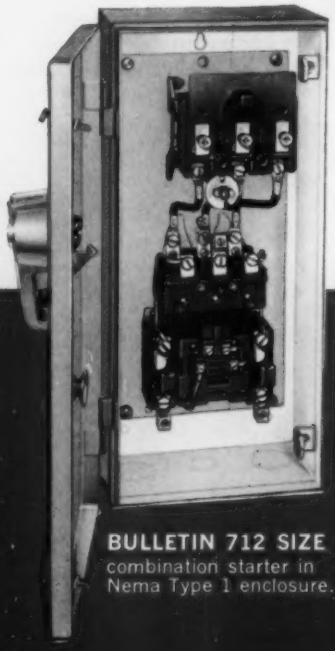
The new enclosures are very "eye appealing." When the open type starters are assembled into special panels, their neatness and compactness will delight the designers. Full details are in Publication 6100. Please write: Allen-Bradley Co., 1329 S. First St., Milwaukee 4, Wis.



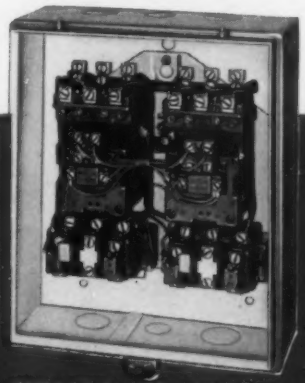
BULLETIN 702 SIZE 3
three-pole, a-c solenoid contactor in Nema Type 1 enclosure.



BULLETIN 705 SIZE 2
across-the-line reversing starter and overload relays in Nema Type 1 enclosure.



BULLETIN 712 SIZE 2
combination starter in Nema Type 1 enclosure.

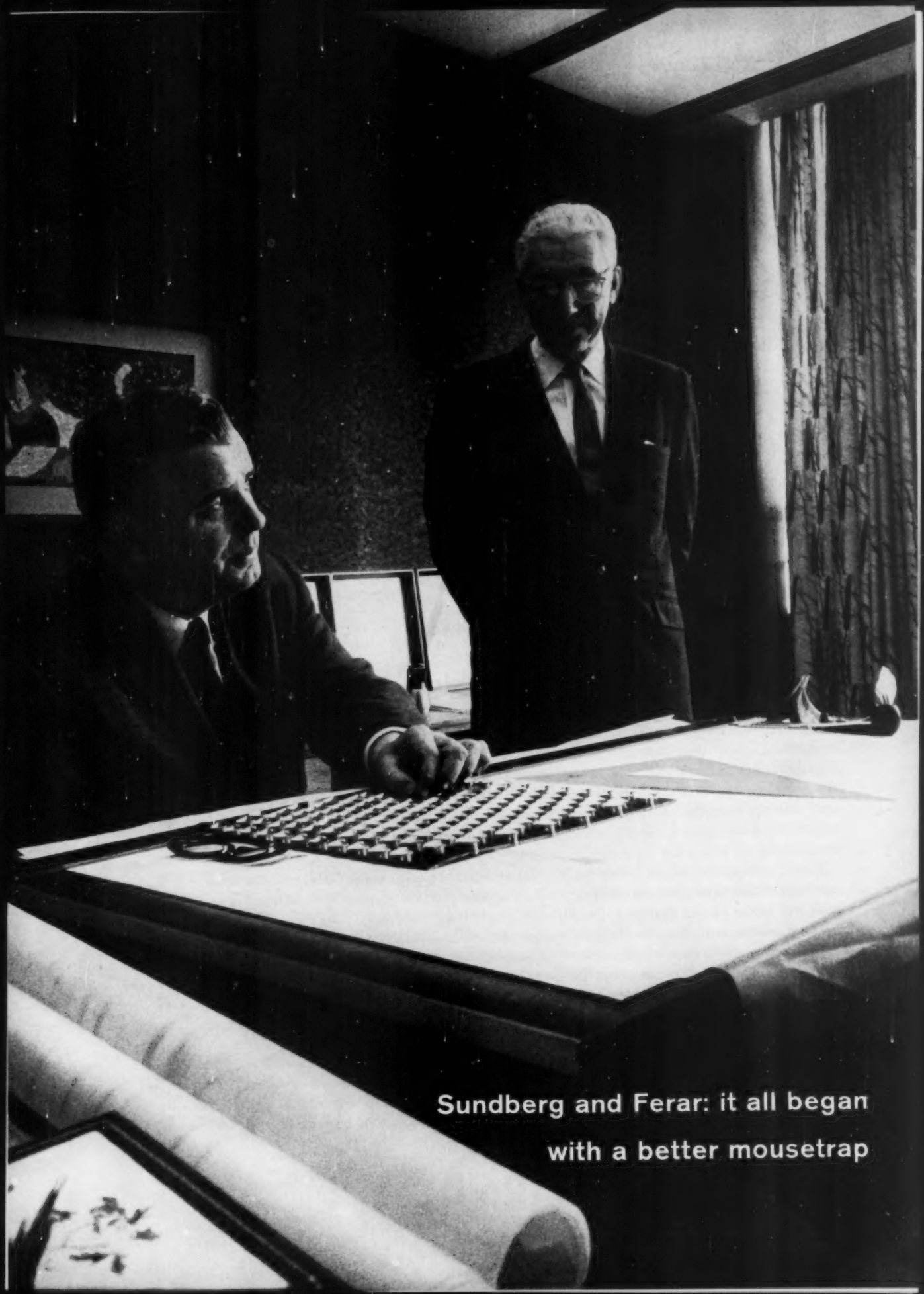


BULLETIN 715 SIZE 1
across-the-line, two-speed starter with two overload relays per speed in Nema Type 1 enclosure.

ALLEN-BRADLEY

Member of NEMA

QUALITY MOTOR CONTROL



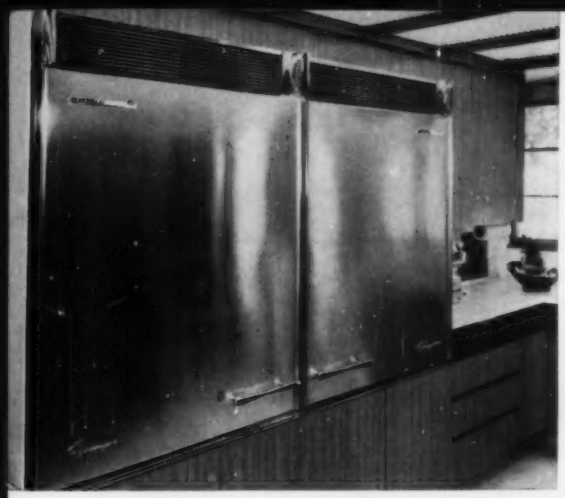
Sundberg and Ferar: it all began with a better mousetrap

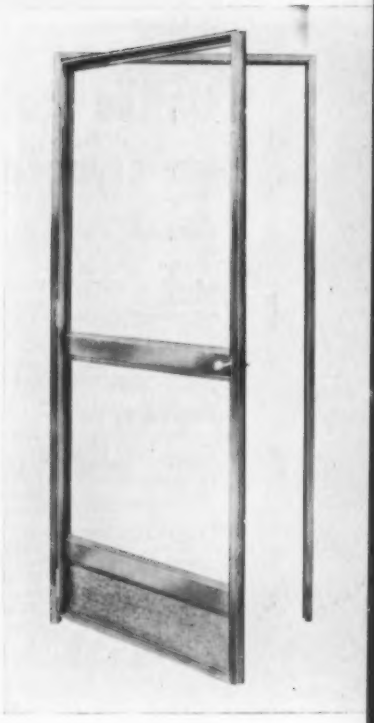
Sundberg and Ferar talk design

When Carl Sundberg and Montgomery Ferar were getting their design firm started during the depths of the depression, one of their first jobs was to build a better mousetrap. It had four holes, and they called it the "Mouseoleum." It sold well, and started them on their way. Today, Sundberg-Ferar is the largest appliance design firm in the United States—7 associates and 70 designers work in an ultramodern headquarters building near Detroit. Over the years, Sundberg and Ferar have never swerved from their premise that the American public has basic good taste. Give shoppers a choice between good and bad and they'll generally pick the better-designed product.

Carl Sundberg contributes a wide range of experience to the firm with a background of art schools and factory production lines. The spectrum of their abilities approaches the complete with Monte Ferar, MIT honor graduate and holder of two degrees in architecture. Since their early days, they have designed products as varied as the clip for an automatic pencil, 5-ton trucks, factories, homes and churches. Millions of consumers are buying and using Sundberg-Ferar-designed automobiles, automatic coffee makers, refrigerators, stoves, and perfume atomizers. Sundberg-Ferar designed the cabinet for UNIVAC, the Remington-Rand computer that predicted the outcome of the 1956 Presidential election. People type on Sundberg-Ferar-designed typewriters, dig holes with draglines they developed, guide boats and airplanes with their navigational equipment, enjoy coffee and soft drinks from Sundberg-Ferar-designed dispensers.

As designers of consumer products (including most of Sears Roebuck's appliance line), Sundberg-Ferar may be the target of criticism from a current school that decries "change for the sake of change." To this observation, Sundberg-Ferar has a response: "Newness is not vulgar, despite what some critics say. Honest newness—and the improvements that go with it—is what is needed. A product can be beneficial and honest to itself—and be





new at the same time. We've got to change and improve to stay alive. In this country it is far more dangerous to be too conservative in your design than to be too advanced," says Montgomery Ferar.

How advanced are Sundberg and Ferar? Consider Monte Ferar's views on the kitchens of tomorrow: "Kitchens have come a long way since the wood-burning stoves of Grandma's day. We've gone from the ornate, to the round, to the current architectural square look. Does design history repeat itself? Not in this case. The squared-off architectural look will be with us as long as we have kitchens. As space becomes more valuable, kitchens will become smaller and we'll have to design to use all the vertical space."

As for appliances, Sundberg predicts a trend to "portable built-ins" designed to be free-standing with a built-in look. Says Ferar: "More and more, Americans are becoming mobile. We want to design our appliances so they will look built-in no matter how many times they're moved."

Ferar also sees refrigerators that will be roomier inside but no larger outside. All major appliances will be matched. "We want women to choose their appliances the same way they now choose their silver," says Ferar.

How do materials fit into the Sundberg-Ferar concept of "newness"? Few materials are newer than today's steels, and no materials are as versatile, as functional and as long-accepted as steel. It's not surprising that Carl Sundberg and Monte Ferar use a lot of steel. "A designer must *know* material—what it is, what it will do," says Carl Sundberg. "He keeps up with new developments. Materials are his clay. He must have empathy with them." About 90 percent of the products Sundberg-Ferar designs use steel because it is usually the material that is functionally suited for the job. Like most designers, they have found steel the most economical, strongest, and most versatile of the materials they use. In an average year, some 500,000 tons of steel go into Sundberg-Ferar-designed products, a far, far cry from the early days of the better mousetrap. USS is a registered trademark.

USS United States Steel

What's new in USS Design Steels

United States Steel demonstrates new alloy for cryogenic service: USS 9% Nickel Steel

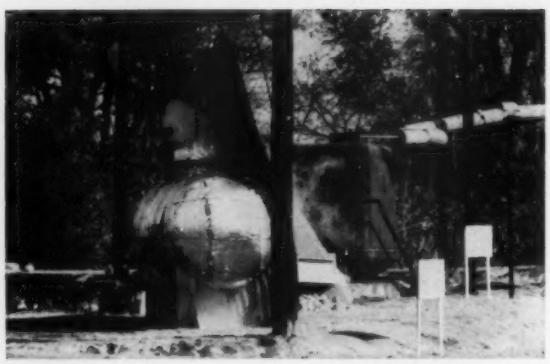
CHEMICAL COMPOSITION

ASTM A-353 Grade	C	Mn	P	S	Si	Ni
A	.13 max.	.80 max.	.035 max.	.040 max.	.15/.30	8.50/9.50
B	.13 max.	.90 max.	.035 max.	.040 max.	.15/.30	8.50/9.50

DESIGN DATA

ASTM A-353 Grade	Tensile Strength psi, min.	Yield Point (0.2% offset) psi, min.	Elongation In 2 in. pct., min.	Allowable Design Stress ASME, psi, max.	Lowest Test Temp. °F. ASTM A-300
A	90,000	60,000	22	22,500	−320
B	95,000	65,000	20	23,750	−320

Modulus of Elasticity, psi — in tension . . . . . about 29 x 10^6; in compression . . . . . about 29 x 10^6



Burst-test for cylindrical-pressure vessels fabricated from USS 9% Nickel Steel, cooled to −320°F, then pressurized to bursting. This one was quenched and tempered—not stress relieved.

USS 9% Nickel Steel was specifically developed for low-temperature storage vessels operating down to −320°F, the boiling point of liquid nitrogen. This new steel has interesting design and money-saving possibilities for a wide range of cryogenic uses.

Recent tests at U.S. Steel's Fairless Works demonstrated the many advantages of USS 9% Nickel Steel. Called "Operation Cryogenics" and conducted jointly by United States Steel, Chicago Bridge and Iron Company and the International Nickel Company, they showed the excellent low-temperature properties of the steel, and that stress-relieving after fabrication is not necessary for vessels of either quenched and tempered 9% Nickel Steel or double-normalized and tempered 9% Nickel Steel. Pressure vessels were cooled to −320°F, then pressurized to bursting. The burst pressure for *all* vessels—stress-relieved or not—was at least *four times* the design pressure. One of the non-stress-relieved vessels did not burst until 2,300 psi. Other vessels of USS 9% Nickel Steel were refrigerated to −320°F and battered repeatedly by "headache balls" with impacts exceeding 80,000 foot-pounds. Results clearly showed that 9% Nickel Steel in the as-welded condition (not stress-relieved) can withstand impacts far beyond any which are likely to occur in service.

USS 9% Nickel Steel is the most economical material available for cryogenic storage down to −320°F which includes liquid ethylene, methane, oxygen, and nitrogen. Its initial cost is lower than either Type 304 Stainless or aluminum alloys of the 5000 series, and its excellent strength properties permit savings from the design stage to the completion of the vessel. USS 9% Nickel Steel has a high modulus of elasticity, high design stress, a low transition temperature, good ductility, ease of fabrication, good weldability and corrosion resistance. It is available in a variety of sizes and shapes: plate, tubing, bars, forgings, piping, sheets and structurals. It can be sheared, gas-cut, cold formed, forged, machined, drilled, punched, hot formed and welded. It can be furnished double normalized (NN), double normalized and tempered (NNT), quenched and tempered (QT), or in the as-rolled condition for subsequent heat treating by the fabricator.

With the trend toward storage and shipment of gas in liquid form, the demand is growing for cryogenic metals that can be fabricated into land and sea-going storage vessels, tanks, intermediate containers, piping and accessory equipment.

The success of the full-scale test program "Operation Cryogenics" is speeding the revision of low temperature codes and specifications to permit the use of quenched and tempered 9% Nickel Steel vessels without post-fabrication stress-relieving. USS 9% Nickel Steel—already more economical in the present double normalized and tempered condition than competitive metals—becomes *most* economical in the quenched and tempered and non-stress-relieved condition. Detailed information is available from United States Steel, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

This mark tells you a product is made of modern, dependable Steel. People look for it on the products they buy.

USS Ex-Ten: new high strength low-cost steel

USS Ex-Ten Steels are sold to minimum mechanical properties shown in this table. Typical chemical compositions are shown for information only.

MECHANICAL PROPERTIES

	EX-TEN 45 Plates, Bars, Structurals, Bar Shapes to ¾" Incl. HR Sheets & Strip, CR Sheets	EX-TEN 50 Plates, Bars, Structurals, Bar Shapes to ¾" Incl. HR Sheets & Strip, CR Sheets	EX-TEN 55 HR Sheets & Strip
Yield Point, psi Min.	45,000	50,000	55,000
Tensile Strength, psi Min.	60,000	65,000	70,000
Elongation, Min.			
Sheets & Strip ⅝ in 2"	25	22	20
Plates & Bars ⅝ in 8"	19	18	—
Cold Bend (specimen bend)			
Sheets & Strip	Flat	D-1T	D-1½T
Plates & Bars	D-1T	D-1T	—

When hot rolled products are ordered annealed or normalized, the mechanical property requirements do not apply.

ASTM Standard Specimens; minimum number of tests and ductility modifications apply.

The newest member of the USS family of 10,000 steels is USS Ex-Ten, a high strength steel with a low initial cost that has major attributes of high strength steels and is ideal for "general range" applications requiring corrosion resistance equal to that of carbon steel.

This new steel is intended to fill the need for an economical grade where greater strength and weight reduction are the primary requirements. Suggested uses: automobile and truck parts, cargo containers, tote boxes, formed building members and many others. It has good ductility and weldability and is available in hot and cold rolled sheets and hot rolled strip, and in plates, bars, structurals, and bar shapes to a maximum thickness of ⅜ inch.

Plates and bars come in two yield strengths: Ex-Ten 50,000 and Ex-Ten 45,000 psi. Hot rolled sheets are available in 55,000, 50,000 and 45,000 psi; cold rolled sheets in 45,000 psi.

USS Ex-Ten has one of the highest strength-to-cost ratios of all steels. Further information is available from United States Steel, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

USS Tenelon: new non-magnetic Stainless Steel for great strength and weight reduction

USS Tenelon is a completely austenitic nickel-free steel that has almost twice the yield strength of the 18-8 grades of Stainless. This enables the designer to work to higher design stresses, cut deadweight and still keep the many advantages of Stainless Steel: strength, corrosion resistance, excellent heat properties and formability.

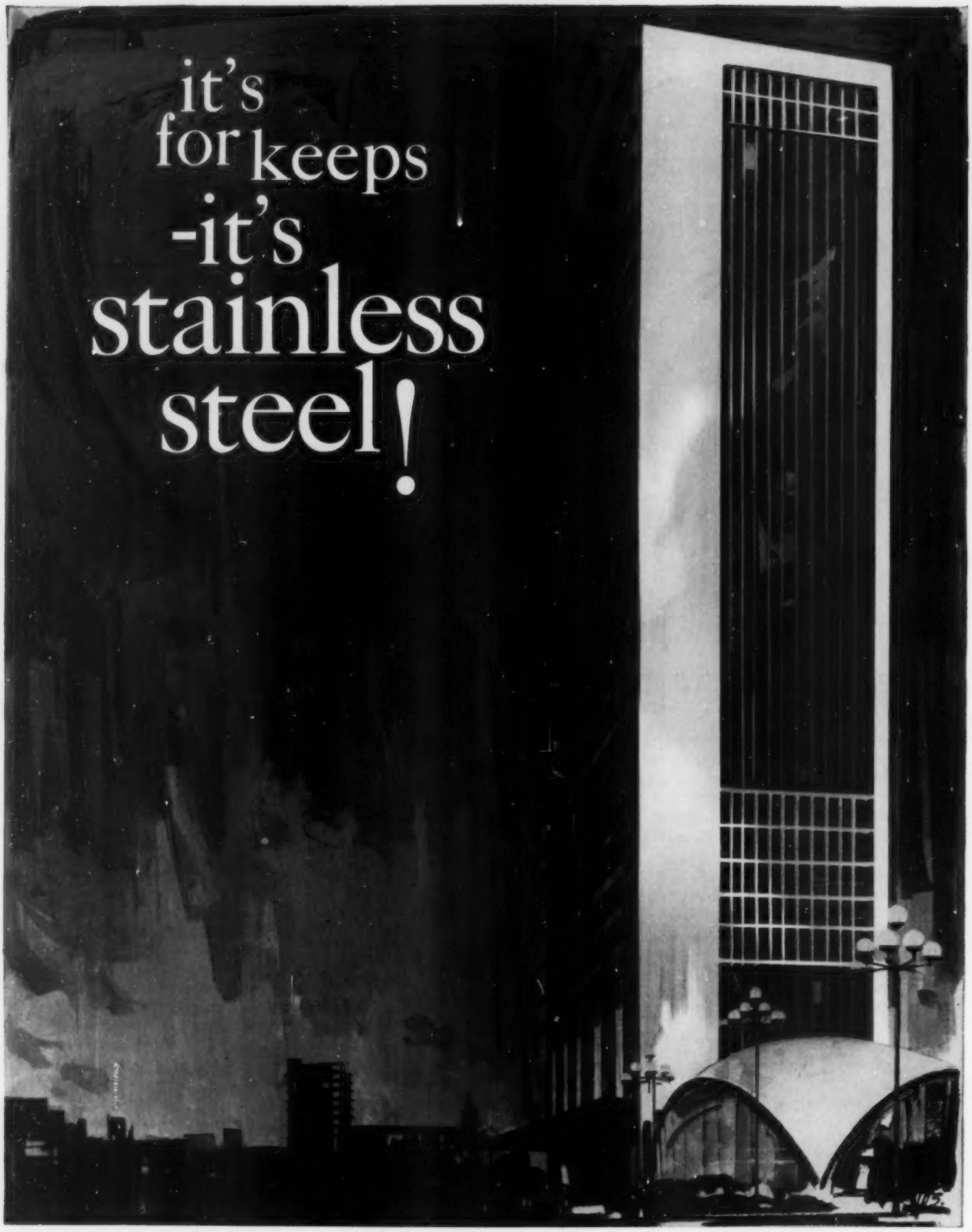
Annealed USS Tenelon has higher mechanical properties than any of the conventional austenitic Stainless Steels. At only 5% reduction, Tenelon has a tensile strength equal to Type 301 Stainless at 18% reduction. At elevated temperatures, Tenelon is superior to 18 Cr-SNi Stainless and is about equal to 18-8 Cb and 18-8 Mo. Charpy V Notch impact strength is 220 ft. lbs. (no break) at 78° and 52 at −200°F.

The corrosion resistance of USS Tenelon has been tested in rural, industrial and marine atmospheres. In rural and industrial atmospheres it is comparable to Type 301 Stainless. In marine atmospheres, it is comparable to Type 430 Stainless. Tests have also been made in chemical plants, oil fields, dairies and even with anti-freeze, and show that Tenelon's corrosion resistance is equal to other Stainless Steels for those applications—and Tenelon is less expensive and has almost twice the strength of most conventional Stainless Steels. In mild acids, its corrosion resistance is about equal to Types 301, 302 and 201; in stronger acids, its resistance is equal to or better than Type 430.

Some suggested uses of USS Tenelon: covered hopper cars (see illustration), passenger cars, automotive vans, tank trailers, fertilizer tanks, high-tensile non-magnetic cables.

Detailed information is available on this new Stainless Steel. For a new booklet, write United States Steel, 525 William Penn Place, Pittsburgh 30, Pa. USS, Ex-Ten and Tenelon are registered trademarks

USS United States Steel



Stainless—the building metal of permanence, economy and beauty.
McLouth Steel Corporation, Detroit 17, Michigan

Look for the **STEELMARK** on the products you buy

McLOUTH STAINLESS STEEL

CIRCLE 47 ON READER SERVICE CARD→

AUXILIARY POWER FOR MINUTEMAN'S THREE STAGES

The U. S. Air Force's Minuteman, first of the solid propellant powered ICBM's, introduces numerous design and operational features unavailable in its first generation counterparts. End result is a smaller, lighter, less complex and lower cost missile.

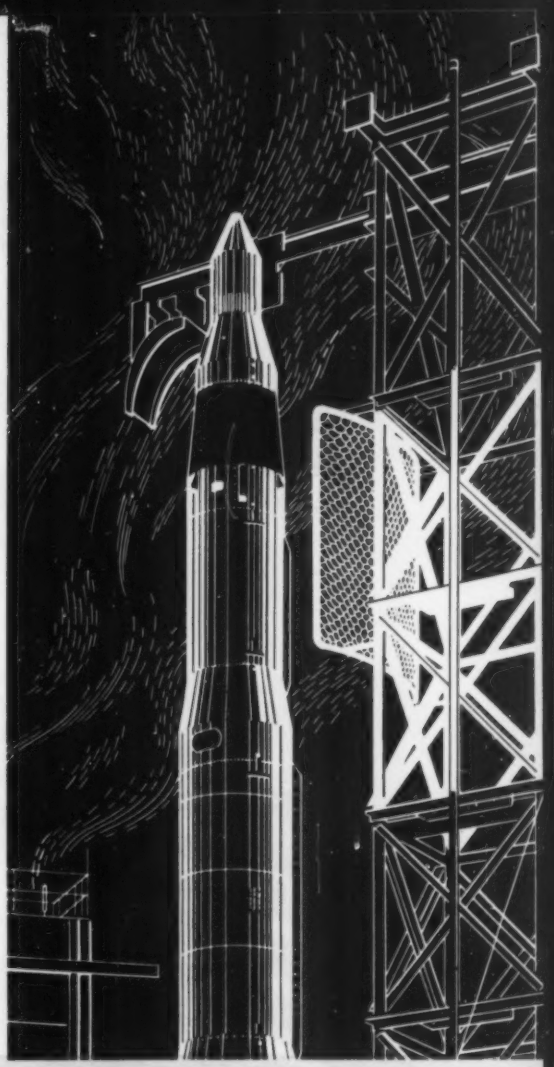
COMPACT DESIGN—Typical of these advances is the highly integrated APU design developed for all three missile stages by Vickers under contract to Autonetics, a division of North American Aviation, Inc. A significant saving in package weight and envelope is provided by immersing the hydraulic pump completely within its self pressurizing reservoir.

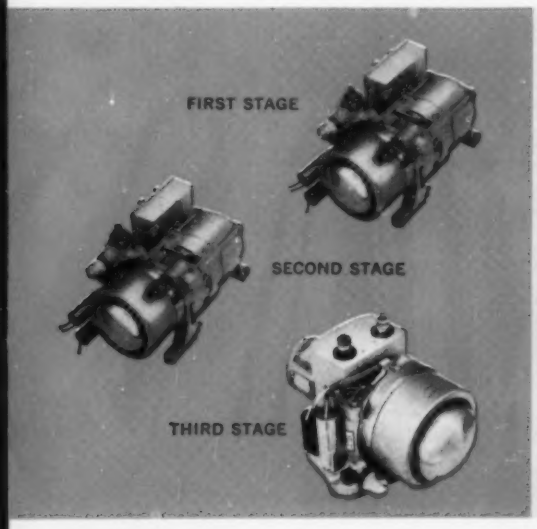
APPLICATION FLEXIBILITY—An important design feature is the ability of the hydraulic pump to be coupled with a wide variety of drives including continuous duty electric motor, ram air turbine, hydraulic motor, flywheel, or be mounted directly on an engine drive pad. For the Minuteman application, an intermittent duty d-c motor is used.

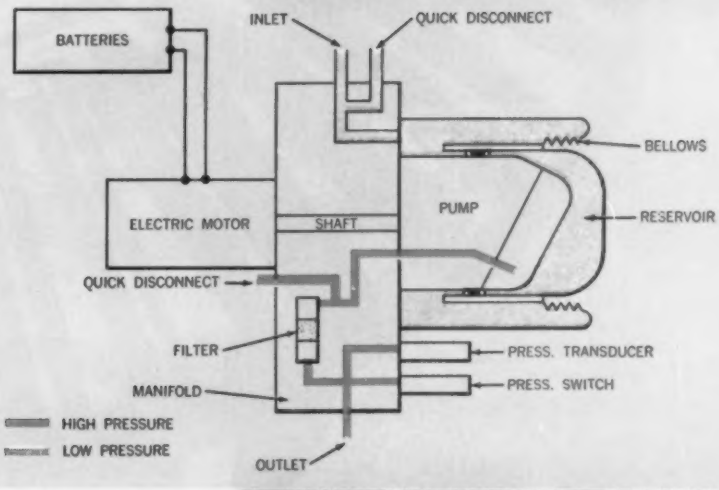
UNUSUAL STORAGE LIFE—A fundamental design goal of the Vickers Minuteman APU was to match the unusual storage life of the missile. This has been accomplished to provide long service-free standby in the missile, coupled with convenient ground check-out.

HIGH RELIABILITY—The schematic diagram below shows the absence of external tubing and the requirement for only one external dynamic seal. These factors along with a proven pumping element and relative low operating speeds have led to a highly reliable system.

This solution is typical of the Vickers "Programmed Power" approach to energy conversion, power transmission and fluid transfer. Get more details on this application by writing for Bulletin A-5249.



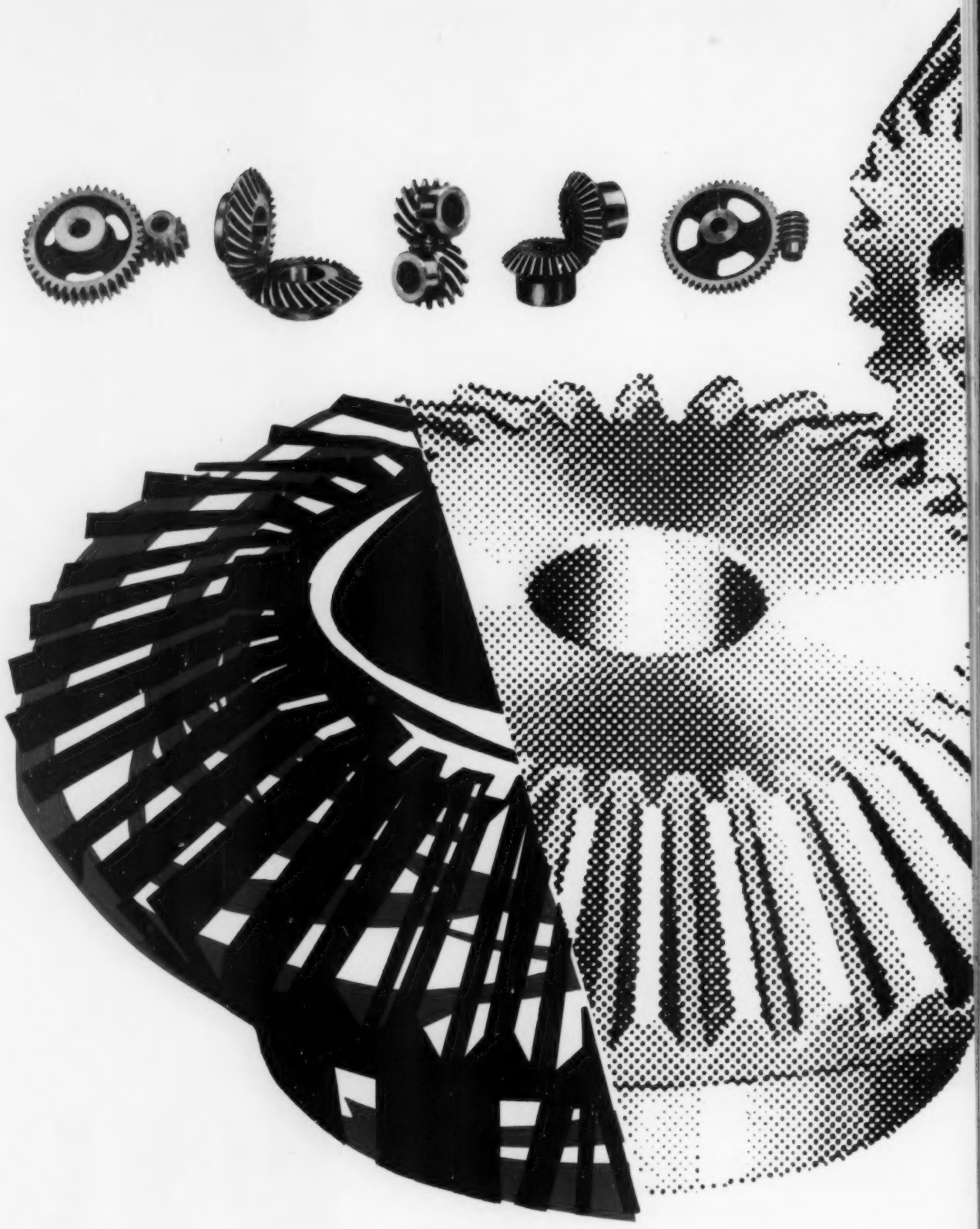




AERO HYDRAULICS DIVISION
VICKERS INCORPORATED
DETROIT 32, MICHIGAN
TORRANCE, CALIFORNIA
division of
SPERRY RAND
CORPORATION

PROGRAMMED POWER IN: FLUID TRANSFER • POWER TRANSMISSION • ENERGY CONVERSION

9421



Morse goes into gear!

with a new line of 20° pressure-angle stock gears at the price of 14½° p.a. gears. Morse introduces a new concept of value by offering 20° p.a. sets designed to replace 14½° p.a. gears. You pay no more and get over 30% more horsepower capacity. Spur, bevel, miter sets, helical, worm-and-gear sets are made from only the finest materials. Gears are produced with minimum plain bores to extremely close tolerances. Finish is excellent. If you're a wise gear-buyer you'll call your Morse distributor now! He's in the Yellow Pages. Morse Chain Company, Dept. 4-91, Ithaca, N.Y.

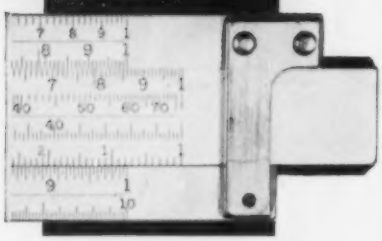
MORSE

A BORG-WARNER INDUSTRY

BW

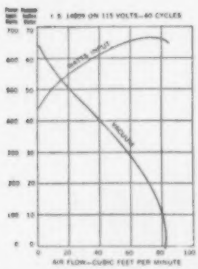
CIRCLE 49 ON READER SERVICE CARD 49

Fractional Horsepower Motors



Lamb® Helps You Select The Right Vacuum Cleaner Motor

9/16 HP, 5-11/16" fan case diameter



IS-14750 thru ventilated

APPLICATION: Domestic portable cleaners.

IS-14809 by-pass ventilated

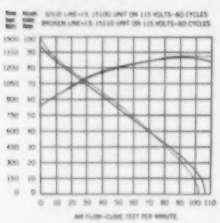
APPLICATION: Wet pick-up portable cleaners and central cleaning systems.

Service Life: Moderate
Cost: Low
Bulletins 101 & 201

NEW

1 HP, 7-3/16" fan case diameter

APPLICATION: Central vacuum systems in particular, also portable commercial wet and dry cleaners.



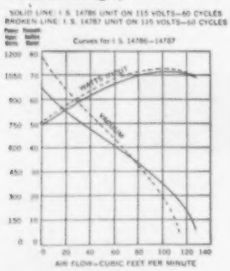
IS-15100 Diffused air discharge

IS-15110 Single air discharge

Service Life: Moderate
Cost: About twice cost of 9/16 HP
Bulletins 251 & 252

7/8 HP, 7-1/2" fan case diameter

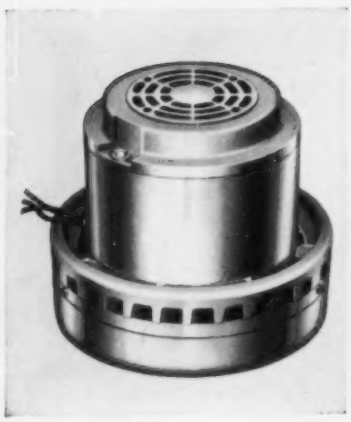
APPLICATION: Portable Heavy Duty Commercial Cleaners and Central Systems (three-stage).



IS-14786 2-Stage

IS-14787 3-Stage

Service Life: Long
Cost: About 3 times cost of 9/16 HP
Bulletin 301



IS-15100 (Diffuser Discharge)

IS-15110 (Single Air Discharge)

Special Requirements of Central Vacuum Systems Met by New High Performance Motor

Existing vacuum motors have been designed to perform best when incorporated into portable vacuum cleaners of standard types and sizes. Such motors are built to produce highest efficiency under air flow conditions that exist in normal domestic and industrial cleaning service and where hoses are of normal length and diameter.

On special applications, like central vacuum cleaning systems that utilize extremely long cleaning hoses, and where tubing losses are present, a special motor is required. To meet this need, Lamb now offers a vacuum motor which will maintain a relatively high vacuum with a modest amount of air flow. The result: these motors operate at high efficiency in the high vacuum range without sacrificing air flow performance under low vacuum conditions.

INPUT – 10 AMPERES at 115 VOLTS

For economical, cleaner design, this rating at Underwriters' test point was selected as the input limit. This allows use of line cord not exceeding number 16 type SJ and control switches of 10 ampere rating.

NEW TAPERED BLADE DESIGN

On central systems which employ centrifugal dirt separation, a small amount of fine dirt and lint must pass through the fan and is discharged outside of the building. For maximum efficiency, this type of fan blade is designed with a long backward curving sweep which, however, may accumulate fine dirt due to centrifugal action. This dirt builds up to a point where starting acceleration dislodges dirt from one blade, resulting in unbalance, noise, and vibration. Special steep angle blades have been used but they also have serious performance limitations.

Lamb research has developed a moderately steep blade angle plus a tapered form. The result is a compromise that yields excellent performance and all but eliminates the dirt loading problem.

CHOICE OF AIR DISCHARGE SYSTEMS

Lint accumulation is minimized and high vacuum is improved in the IS-15110 with a single tangential discharge pipe. This allows for easy connection to a discharge piping system, if desired.

The IS-15100, by discharging air through slots in the fan case, results in better noise suppression.

FAN-END BEARING IS PROTECTED BY AIR COOLING

Motors in central vacuum systems are often required to operate for long periods of time under sealed conditions – which results in a high temperature rise in the fan system. In ordinary by-pass type motors, the electrical parts have a separate cooling system, but bearings in the adjacent fan case often become hot enough to destroy the lubricant. Early failures can and do result. Lamb's new motor prevents this by providing a unique ventilating system which directs cooling air over the fan-end bearing and protects the motor from harmful heat built-up within the fan case. For complete details, write to Lamb Electric Company, Kent, Ohio – ask for bulletins shown at left. *Also available – explosion-proof model. Ask for bulletin 401.*

CIRCLE 50 ON READER SERVICE CARD

Buy where you get America's widest selection of standard balls . . . the most extensive range of ball sizes in standard basic materials. Establish one source big enough to service all your requirements and be sure of uniformly high ball quality, always.

While quality is the keynote, service is equally important! That's why new facilities, equipment and production techniques are constantly being added in a continuing program designed to serve you better.

You can rely on the Hoover Ball Division, with duplicate manufacturing facilities in Middletown, Ohio and Erwin, Tennessee, for your specific requirements for high quality balls.

hoover

BALL DIVISION
P. O. Box 381, Middletown, Ohio
hoover ball and bearing company

Hoover Ball Division PE-9
Hoover Ball and Bearing Company
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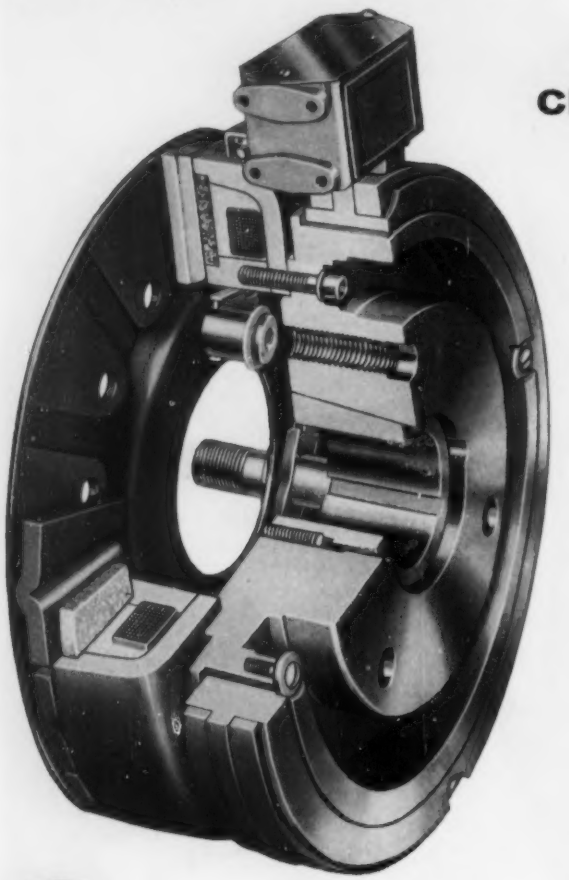
Title_____
Company_____
Address_____
City_____ Zone_____ State_____

CIRCLE 51 ON READER SERVICE CARD

EATON
DYNA-TORQ®
MAGNETIC-FRICTION CLUTCHES and BRAKES



The Ideal Solution to Exacting Clutching and Braking Problems

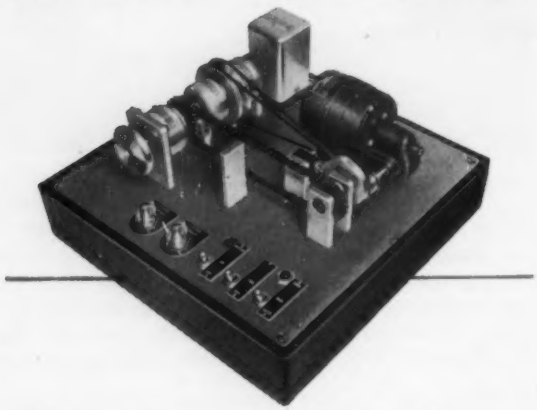
These highly responsive, trouble-free units provide accurate control of intricate automatic machinery. Operating on 6, 12, 24 or 90 V.D.C., Dyna-torQ units may be actuated by micro-switches, photo-electric cells, relays or any "ON-OFF" signal to perform a wide range of functions in processing and fabricating applications. The compact rectifier type control converts AC power to DC power and may be remotely mounted out of busy machine areas.

Eaton Dyna-torQ Clutches and Brakes are available from 1¾" through 15" in diameter. They may be easily and quickly installed on either new or existing plant equipment. Exclusive features of design and construction mean worthwhile savings.

HP @ 1800 R.P.M. *(Typical Application)*

MODEL	HP	MODEL	HP
302	1/20	308	7½
303	⅓	310	10
304	1	312	20
305	2	315	25

Dyna-torQ Distributors in many principal cities carry Dyna-torQ Clutches and Brakes in stock for immediate delivery.



EATON

ACCURATE POWER CONTROL

DEPENDABLE MOTION CONTROL

RAPID RESPONSE • LOW MAINTENANCE COST

EASY BUILT-IN INSTALLATION

WIDE RANGE OF SIZES AND CAPACITIES

Send for Illustrated Literature.

Ask your Dyna-torQ Distributor to demonstrate Dyna-torQ in action and see for yourself the many possible applications for Dyna-torQ in Motion Control and Power Transmission.

EATON — *DYNAMATIC DIVISION*
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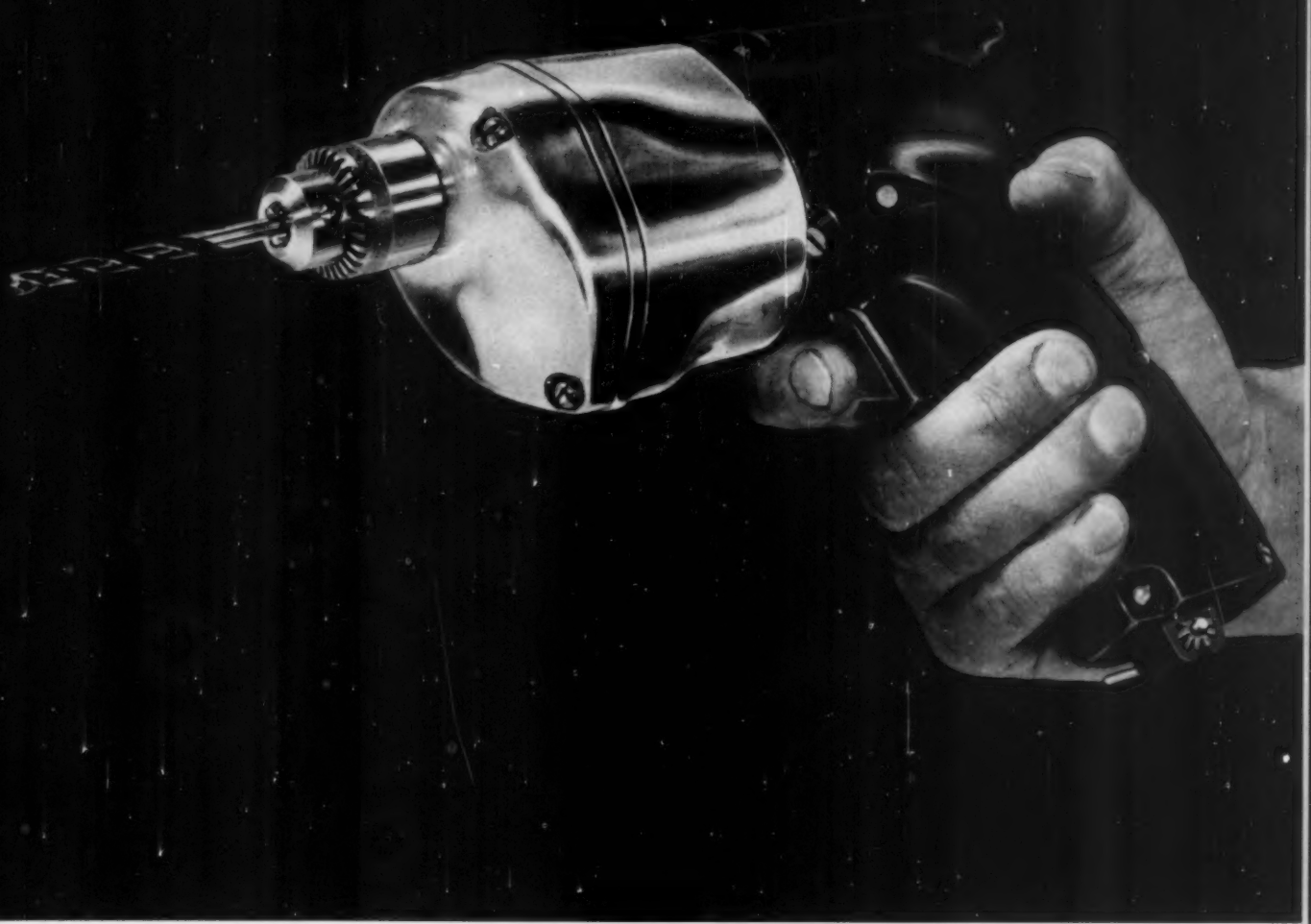
3122 FOURTEENTH AVENUE • KENOSHA, WISCONSIN

CIRCLE 52 ON READER SERVICE CARD

CIRCLE 53 ON READER SERVICE CARD→

TEAMWORK BEATS SCHEDULE IN MARKETING FIRST CORDLESS DRILL



DIES DESIGNED AND CASTINGS DELIVERED IN THREE WEEKS BY DOEHLER-JARVIS!

A 'breakthrough' product means a race against time. Get it in production and on the market while it is still "hot" news.

That was the situation Black and Decker faced in developing the first "cordless" electric drill.

A major time factor—the design and construction of dies and the die casting of three major elements of the revolutionary new product.

The question put to Doehler-Jarvis—can you design and build the dies and deliver aluminum castings for the gear case, gear case cover and field case in three weeks?

The answer—we did it!

The first delivery of completed castings was made in three days less than three weeks.

This is *not* a routine situation. But it is an outstanding example of how Doehler-Jarvis' 57 years of leadership in die casting can work to your benefit in all circumstances. It was the design and engineering skill and experience of Doehler-Jarvis, together with their unmatched production facilities and know-how which helped Black and Decker meet its ultra-tight production schedule.

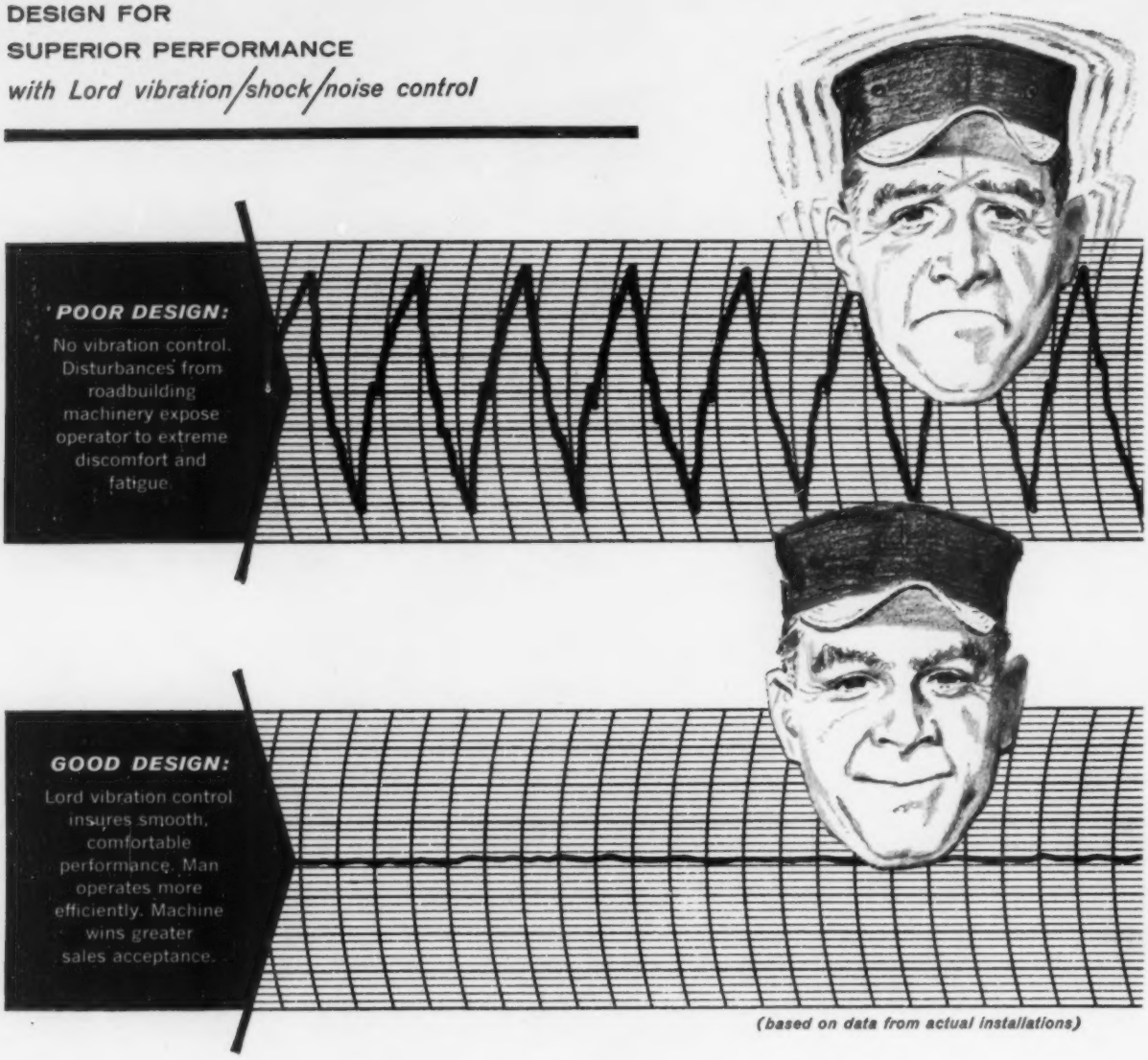
But there was more to gain than speed. The die cast parts delivered to Black and Decker have the high strength, impact resistance and abrasion resistance needed to take rough handling; they are sound and dimensionally stable to permit and maintain close tolerance; and their attractive finish adds extra sales value.

You will find it to your advantage to talk to Doehler-Jarvis about die castings for your products. Contact the office nearest you.

Doehler-Jarvis

Division of National Lead Company • General Offices: Toledo 1, Ohio
Plants and Sales Offices: Toledo, Ohio; Grand Rapids, Michigan; Pottstown, Pennsylvania; Batavia, New York.
In Canada: Barber Die Casting Co., Ltd., Hamilton, Ontario.
In Brazil: Industrias Doehler do Brasil, S. A., Sao Bernardo do Campo, Sao Paulo.
In Argentina: Doehler Argentina, S. A., Buenos Aires.
In Great Britain: Metal Castings-Doehler, Ltd., Worcester, England.

DESIGN FOR
SUPERIOR PERFORMANCE
with Lord vibration/shock/noise control


POOR DESIGN:
No vibration control. Disturbances from roadbuilding machinery expose operator to extreme discomfort and fatigue.
GOOD DESIGN:
Lord vibration control insures smooth, comfortable performance. Man operates more efficiently. Machine wins greater sales acceptance.

(based on data from actual installations)

is your product designed for humans?

Operator comfort is an increasingly vital aspect of good design.

Users of your products—truck drivers, farmers, heavy equipment operators—prefer and *today expect to get* smooth-performing equipment. Objectionable noise and vibration can be costly—returned equipment, lost sales, damaged prestige.

Today's products must be designed for humans . . . and this is where Lord can help. High-strength elastomeric mountings and joints can be custom designed to isolate the operator from dynamic disturbances. Gone will be the jarring, rattle and roughness that are dead giveaways of poor design.

Instead you will have a vehicle that rides better, sells easier and stays sold.

Remember this: product designs that start with Lord vibration/shock/noise control end up with a competitive edge. See our product guide in Sweet's Design File. Better yet, contact the nearest Lord Field Engineering Office listed here or the Home Office, Erie, Pa.

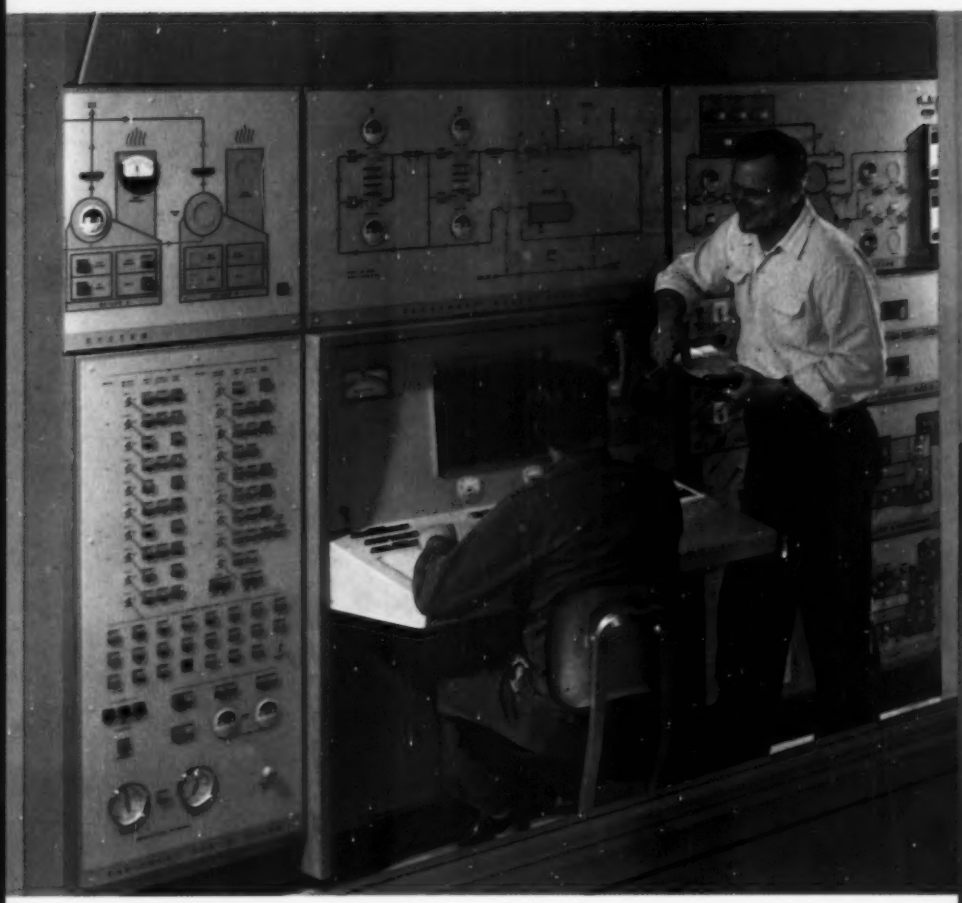
LORD®

FIELD ENGINEERING OFFICES

ATLANTA, GEORGIA - CEdar 7-9247
BOSTON, MASS. - HAncock 6-9135
CHICAGO, ILL. - Michigan 2-6010
DALLAS, TEXAS - Riverside 1-3392
DAYTON, OHIO - BAldwin 4-0351
DETROIT, MICH. - ELgin 7-2150
KANSAS CITY, MO. - WEstport 1-0138
LOS ANGELES, CAL. - HOllywood 4-7593
NEW YORK, N. Y. (Paramus, N. J.)
New York City - BRyant 9-8042
Paramus, N. J. - DIamond 3-5333
PHILADELPHIA, PA. - PEnnypacker 5-3559
SAN FRANCISCO, CAL. - EXbrook 7-6280
WINTER PARK, FLA. - Midway 7-5501

"In Canada—Railway & Power Engineering Corporation Limited"

LORD MANUFACTURING COMPANY • ERIE, PA.

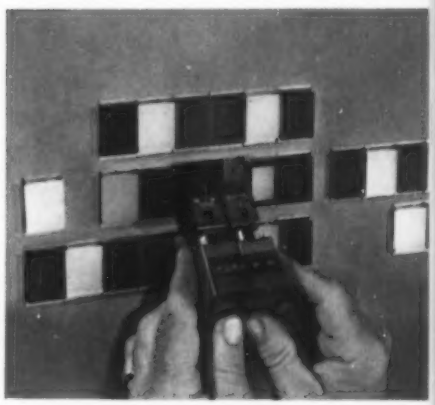


Save 50% on space. Indicator and switching unit are combined in one device to save panel space.

Start your panel design with the

Reliability, Styling and Flexibility of MICRO SWITCH lighted push-button switches

The flexibility of MICRO SWITCH "Series 2" lighted push-button switches enables you to precisely tailor your control panel to your requirements. Hundreds of switch and indicator combinations can be assembled by simply snapping together the correct modular parts. Their clean, modern styling complements your panel design without dominating it. Most important, any of the 18 switch units you select has MICRO SWITCH reliability. That's why these "Series 2" switches serve on some of the most crucially important control panels in the world. Write for the colorful Catalog 67, or see the Yellow Pages for the nearby MICRO SWITCH Branch Office.



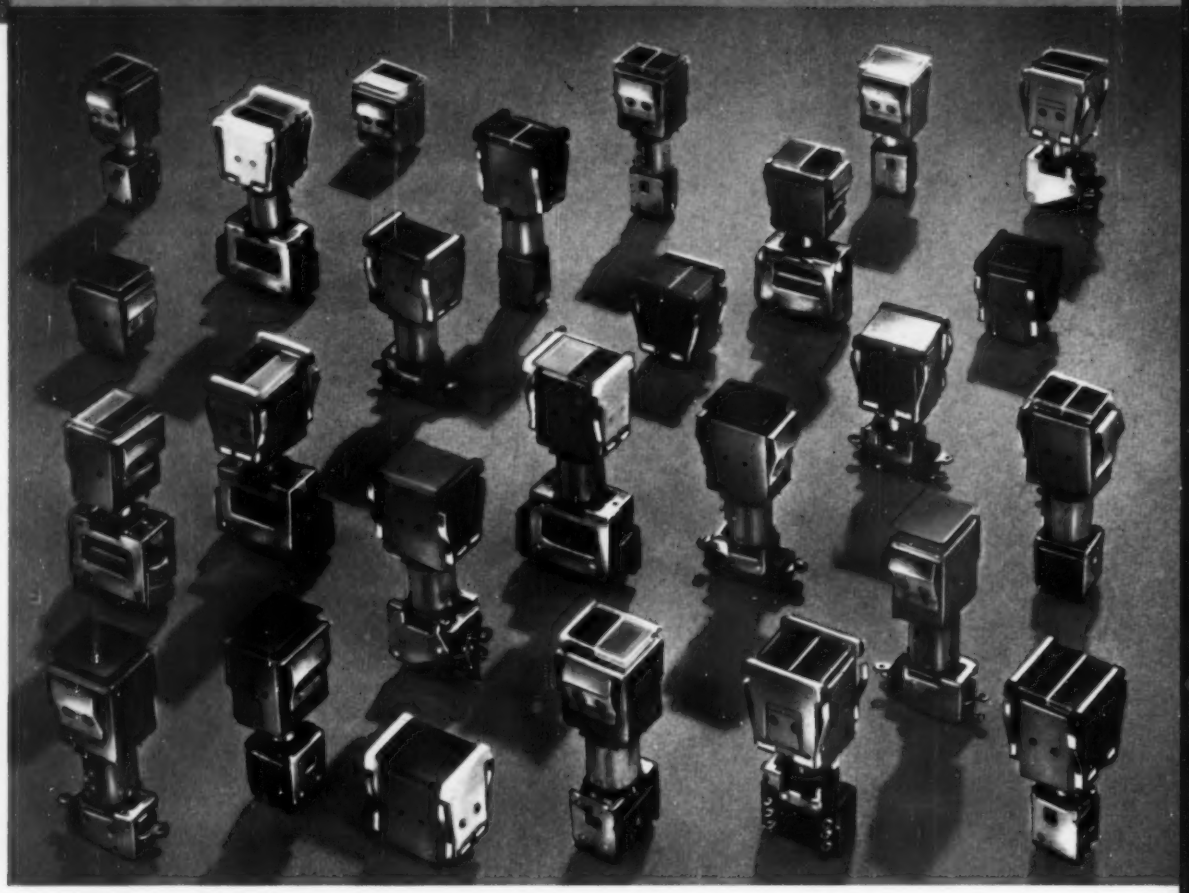
It's a snap! Modular parts snap together and then snap into panel slots without tools.

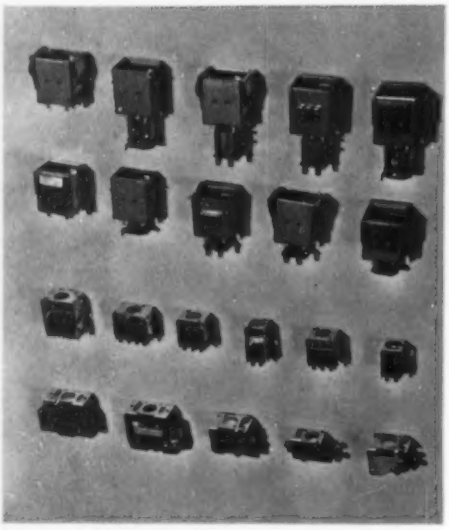
MICRO SWITCH . . . FREEPORT, ILLINOIS
A division of Honeywell
In Canada: Honeywell Controls, Limited, Toronto 17, Ontario

Honeywell
MICRO SWITCH Precision Switches

HONEYWELL INTERNATIONAL
Sales and service offices in all principal cities of the world. Manufacturing in United States, United Kingdom, Canada, Netherlands, Germany, France, Japan.

MICRO SWITCH Precision Switches





Eighteen different switching units are available to match virtually all circuitry requirements.

Hundreds of switch and indicator combinations ...with MICRO SWITCH reliability

The functional color combinations on "Series 2" switches can be split laterally or longitudinally. Up to four colors can be used behind each display screen. Projected color makes it possible for the display screen to change color to indicate a change in the circuit.

Available switching units include hermetically sealed units, small but rugged long-life types and space-saving subminiature assemblies. Momentary-contact or alternate-action units are available in a choice of circuitry to exactly match requirements. Insist on MICRO SWITCH reliability by specifying "Series 2" push-button switches for your panel. You may obtain prompt engineering help by simply checking the Yellow Pages for the MICRO SWITCH Branch Office. Send for Catalog 67.

MICRO SWITCH . . . FREEPORT, ILLINOIS
A division of Honeywell
In Canada: Honeywell Controls, Limited, Toronto 17, Ontario

HONEYWELL INTERNATIONAL
Sales and service offices in all principal cities of the world. Manufacturing in United States, United Kingdom, Canada, Netherlands, Germany, France, Japan.

Honeywell
MICRO SWITCH Precision Switches

Some Ideas

for your file of practical information on drafting and reproduction

KEUFFEL & ESSER CO.

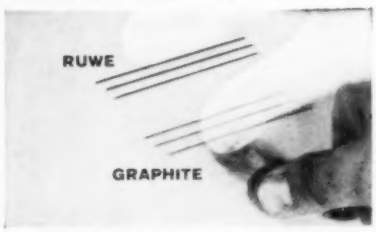
The stone tablet and chisel were pretty widely used writing and drawing instruments in their day.

But they don't command much of a following any longer. Like so many tools of the past, they gave way to better methods of portraying information. Some of these methods occurred by accident, some were developed by experts to serve specialized needs. Three good examples of the latter are described here.

A Couple of "Better" Pencils

When polyester drafting film first came into use, it was found that standard graphite pencils with clay binders, while fine for paper, smudged too readily on film.

So a new kind of pencil was needed—and developed. It was called the Duralar. With both binder and color agent made entirely of plastic, Duralar deposited a black, dense line on film, which could neither be smudged nor washed away.



But since washability is not the touchstone of every drafting operation, K&E went a step further. Result – the Ruwe pencil. Having all the "fine feel" and erasibility of graphite, on both film and cloth, the Ruwe deposits a blacker, denser line than graphite, with the smudge resistance the old graphite pencil could not provide.

Here's why: the Ruwe pencil *is* graphite, but with a plastic binder instead of clay. Color coded in five degrees of hardness from 2S to 6S, Ruwe is available in wood pencils and leads. More good news is that Ruwe is now available in 2S and 3S hardnesses for fine-line automatic pencils as well. The lead is just .036" in thickness – ideal for free-hand lettering.

It's interesting to note, that since the introduction of Ruwe, other plastic-graphite pencils have been placed on the market. If you're interested in testing the original we'll send free Ruwe pencils to you – just send the coupon.

Now You See 'em... Now You Don't

For engineering drawings, or freehand sketches, K&E GUIDE LINE[T.M.] tracing papers, cloths and films make light work for you – by making light *work* for you. The light blue cross-section lines are visible to the eye, but will not reproduce on your diazos or blueprints. Other companies make similar products but here's the important K&E contribution: GUIDE LINE is now available in the widest variety of drafting media ever. Specifically: ALBANENE® and CRYSTALENE® 100% rag stock tracing papers, PHOENIX® water-resistant tracing cloth and HERCULENE® polyester base drafting film. So whichever sheet you use, odds are it's available in GUIDE LINE first.

We especially recommend GUIDE LINE products for accurately guiding freehand work such as plant layouts, organization charts, electrical diagrams, etc. Your freehand work actually will look more like a finished detail than a sketch. And confidential notes will drop out too, if written or typed in special colors.

Available in a wide variety of grid sizes, GUIDE LINE comes in rolls or pads on ALBANENE and CRYSTALENE, in rolls on PHOENIX and HERCULENE, and can be supplied with your own title block or special heading.

Send for some free samples and the GUIDE LINE brochure.

Through The Looking Glass

No more "Alice in Wonderland" wandering about when you want to locate the graph sheet you need for a specific job. Reason – K&E graph sheets now are packaged with a new "looking glass" – A time-saving *visual* package. This unique package has a window in the front so you can see the sheet inside. This is a boon, especially if you use a wide variety of graph sheets. Apart from the packaging, we've done a few other things to make graph-sheet selection easy and infallible.

Every user of graph paper puts it to a different task. So we have put together a complete line of graph papers, one or more of which will almost certainly meet your particular requirements. As a matter of fact, odds are 1000 to 1 that we already make and sell the sheet you require. In the event that we don't, we'll work with you to create it.

And we bend over backwards to make sure every sheet with the K&E symbol more than does its job. To insure accuracy of performance, every K&E graph sheet ever made was printed from precision-engraved plates by the letterpress process. The paper used – translucent or opaque – has at *least* 50% rag content – 100% in some cases. And before any of it ever gets to the printer, it undergoes extensive examination in our quality control labs.

There is a lot more we could tell you about K&E graph sheets. We have prepared a selection guide for your use. If you'd like to have one, it's free, along with some sample sheets in the new *visual* package.

12,300 variables at a glance. Here's a typical stock market chart used to study relative market action. Center line is market behavior of 540 stocks over 20-year period. Two basic stock groups of 25 and 50 individual stocks, averaged, are plotted against market (figured at zero per cent). Resultant chart shows all-important slope of curve which – far more than gross increases – tells the story of the stocks' vitality. No list of statistics, no matter how exhaustive, could give the relative interactions shown here. This picture is possible only with a graph.

KEUFFEL & ESSER CO., Dept. PE-9, Hoboken, N. J.

Please send me free:

☐ Ruwe Pencils ☐ GUIDE LINE[T.M.] Brochure and Samples

☐ Graph-paper Selection Guide and Samples

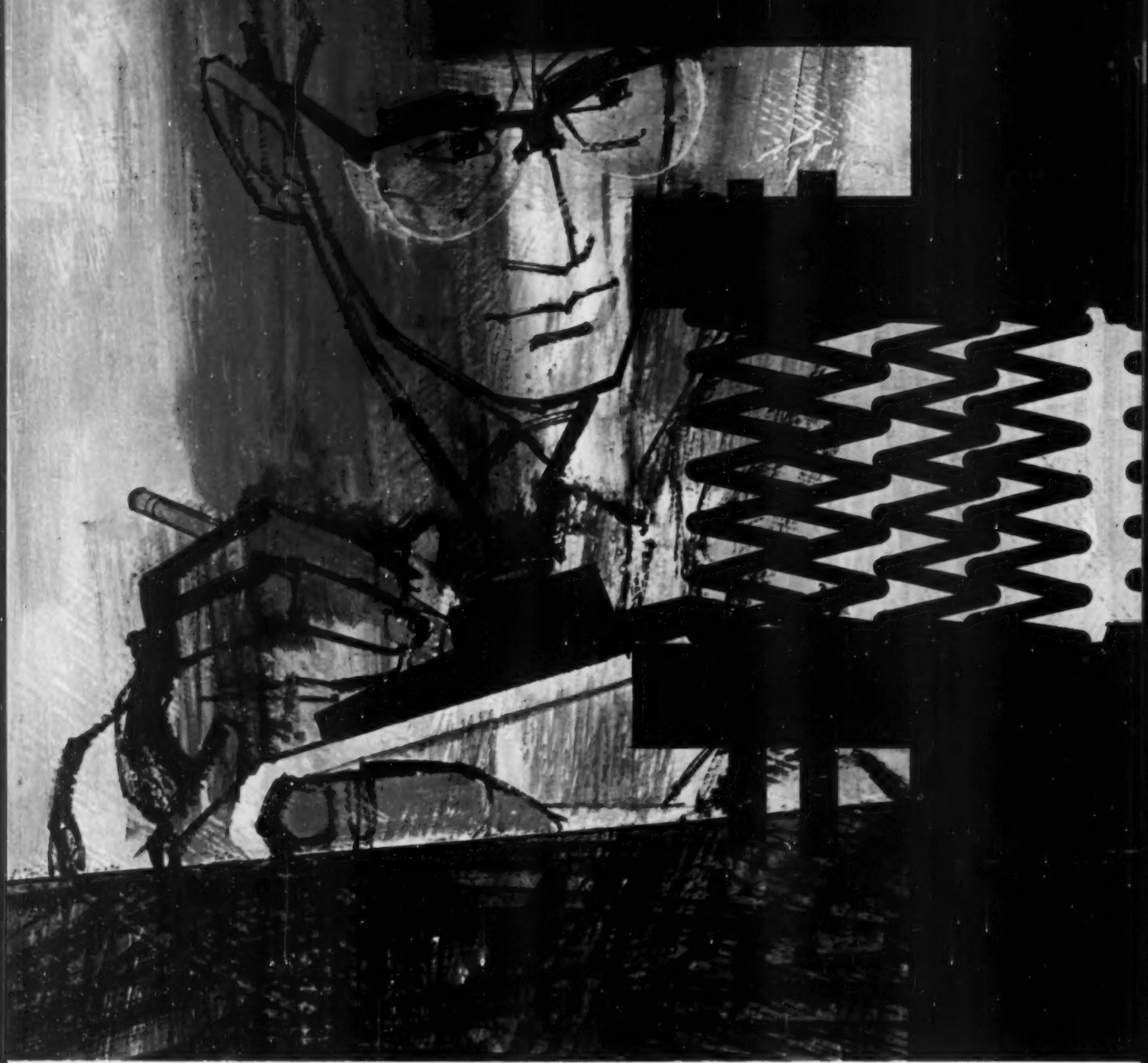
Name & Title_____

Company & Address_____

4234

CIRCLE 57 ON READER SERVICE CARD

CIRCLE 58 ON READER SERVICE CARD →



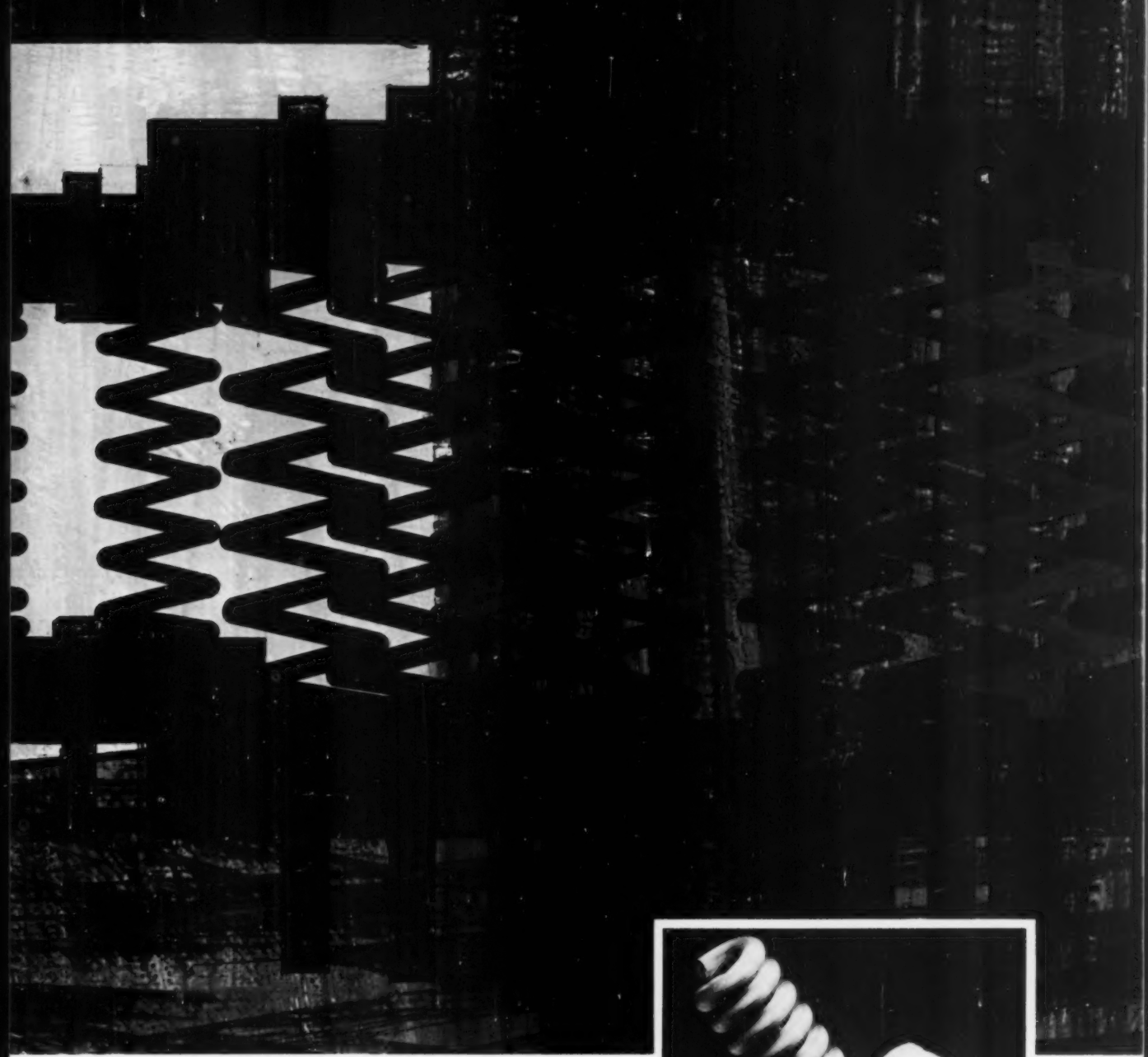
New N-S stainless wire tests 100,000 psi

From National-Standard research and development comes NS-355—a stainless steel, corrosion resistant spring wire having much greater elasticity than conventional stainless steel wire.

NS-355 is a semi-austenitic alloy, originally developed for use in heavy wire sections fabricated from bar, billet or plate stock—applications requiring corrosion resistance, strength, durability and hardness. National-Standard searched for a way to apply these outstanding advantages to highly stressed spring wire applications.

After comprehensive research in processing methods, National-Standard metallurgists developed the capability to draw NS-355 alloy into exceptionally high-tensile spring wire. Spring production tests were made on .125 and .075 inch diameter wire samples with a tensile strength over 100,000 psi higher than music spring wire, proving that NS-355 wire could be satisfactorily run on automatic coiling machines with excellent formability.

Further evaluation tests were conducted in the Spring Laboratory of Bendix Corporation, South Bend, Indiana. Here, engineers ran life cycle tests on NS-355 stainless steel springs and determined spring modulus values. On a mechanical cycling unit—eight springs to a fixture—NS-355 springs



above music wire

were subjected to 600 compression cycles per minute—a total of 10-million cycles under stresses from 20,000 to 150,000 pounds.

The development of NS-355 stainless steel spring wire creates an entirely new solution to highly stressed, corrosion resistant spring requirements for jet engines, food and beverage equipment, chemical machinery and a growing number of other special wire applications.

For more information about new NS-355 stainless steel spring wire, or help in developing high quality wire to meet your special or unique applications, write National-Standard Company, Niles, Mich.

National-Standard NS-355 stainless steel springs with an index as low as 3 can be formed on automatic coiling machines without breakage.

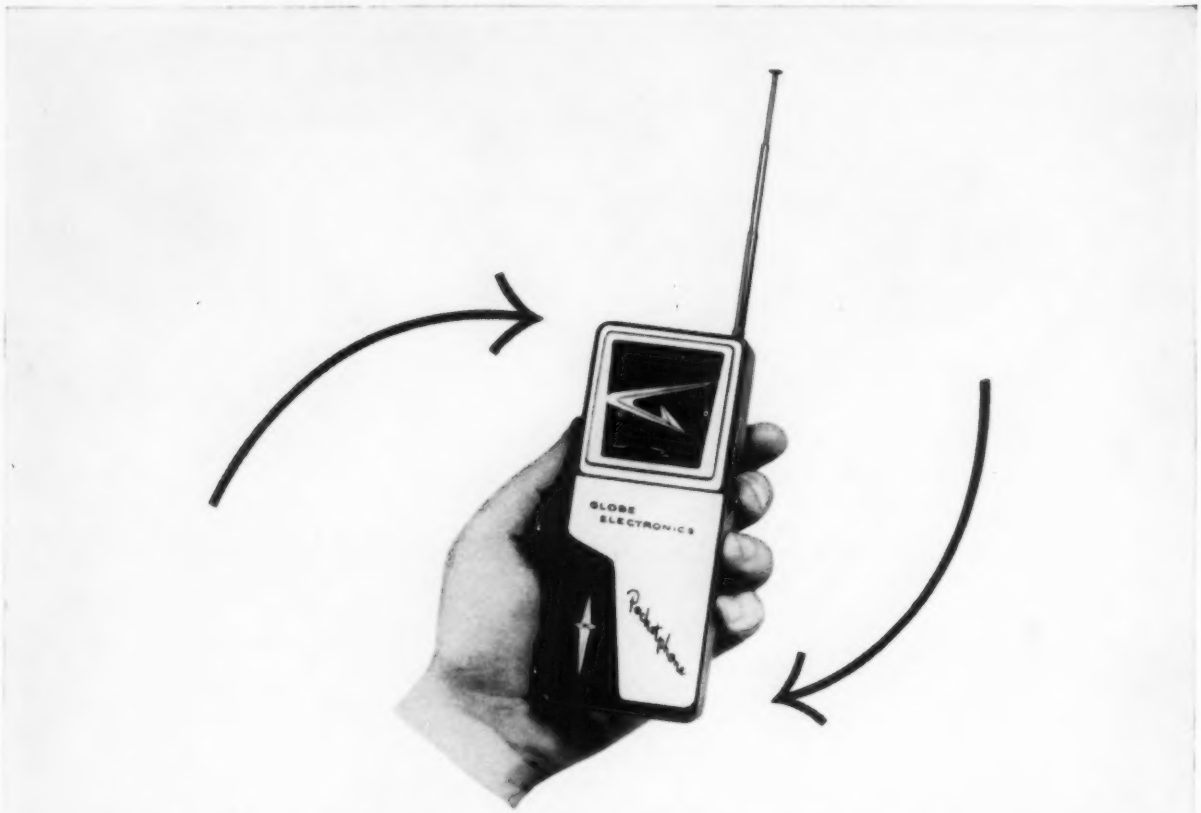
NS NATIONAL-STANDARD COMPANY

Manufacturer of Specialty Wire & Metal Products

NATIONAL-STANDARD COMPANY

Niles, Michigan

61-W03



A jolt-taking, better looking case at a savings in cost

Globe electronics was faced with a challenge . . . perhaps you have a similar one right now. They wanted their new, tiny 'Pocketphone' 2-way radio to have a modern case with eye appealing design and a rich lustrous finish. It had to be a thin walled material of high impact strength. Added to these was the important factor of cost.

Once again, CMPC—in consultation with Globe design engineers—was called upon to exercise its more than 40 years of experience in solving unique engineering problems. ABS was chosen as the material which best met all needs—including cost. Now, this smallest 2-way radio's outside case, battery case, and send-receive knob are custom molded by CMPC.

Why don't you bring your manufacturing challenges to a Chicago Molded engineer. He'll have the right answer for you.

Send for new brochure "Design and Purchase of Custom Molded Plastics".

CMPC

CHICAGO MOLDED PRODUCTS CORPORATION
1020 D North Kolmar Avenue
Chicago 51, Illinois

DEVELOPMENTS TO WATCH

A "totally new" **epoxy resin showing "very good strength, heat stability, and improved storage life"** has been developed by Allis-Chalmers. And, company engineers say, the resin offers the special advantage of requiring no separate catalyst. **Only heat is required for hardening.** The material is now in the final evaluation stage and patent applications are being filled. Additional information should be available later in the year.

Also under development at A-C: an **improved** route to production of **nodular iron,** using new-type stirrers to improve innoculation techniques. A-C says its Research Div scientists have made stirring paddles of recently synthesized materials "stable at temperatures far above those at which metals can serve" and showing "excellent endurance in thermal shock." These, A-C says, have not only shown the ability to stand up in the molten metal and to accelerate the mixing of innoculating agents with gray iron, but also seem to **reduce sulphur content substantially.**

• • • •

A **free-piston engine, "cheaper**—even in small sizes—**than a diesel and less expensive to operate"** is claimed by a Canadian inventor. It's now going into commercial production in Canada, has been licensed for manufacture in the US.

Key to the lower cost, its inventor says, is a streamlining of design that provides a **single lever control for the fuel** and eliminates need for recirculation of air or throttling for part-load operation.

Prototype models are in the 80-hp size, and have a weight/power ratio of 5 lb/gas hp; but new designs are expected to achieve a ratio of 3 lb/compressed gas hp and a specific fuel consumption as low as 0.33 lb/hp-hr.

Free Piston Development Co, Kingston, Ontario, Canada holds the patents; Ingersoll Machine & Tool Co., Ltd will be the first commercial producer.

• • • •

Titanium looks like a "natural" **for tinplating equipment** and hot-dip soldering machines. The reason: tests at Tin Research Institute indicate that **even after more than 200 hr of immersion in molten tin at 600 to 650 F,** no **wetting or attack on the titanium is apparent.**

When oxygen is excluded, though, tinning does occur—and quite rapidly. Thus oxygen seems necessary for protection. TRI metallurgists theorize that this is because, in the presence of oxygen, titanium forms a surface film that protects it from attack. Other tests, in argon and zinc chloride, confirm the theory.

Says C. J. Thwaites of TRI "titanium could be a practical substitute for materials such as steel and cast iron in cases where there is contact with molten tin but where wetting and attack by the molten metal must be avoided. Examples are pipework and valves for controlling the flow of molten tin, solder or bearing metal, the moving parts of mechanized hot-dip tinning machines, and jigs and manipulating gear used in the hot-dip tinning of fabricated articles or similar instances where contact with fused flux is intermittent."

• • • •

A radioisotope yarn gage, expected to find application in production of wire mesh as well as in weaving conventional fabrics; **and an isotopic system for testing** uniformity of **application of textile lubricants** are under development at Britain's National Chemical Laboratory.

The thread gage is a source-and-detector unit, basically similar to a nuclear thickness gage. (The amount of radiation that gets through the thread, going

from source to detector, is proportional to weight and thickness of the thread.) Here, the radiation source is Krypton 85; the detector an ion chamber, compensated for temperature and humidity. The device will measure variations in mass per unit length in threads from 50 to 300 denier, regardless of the fiber cross-section.

The lubricant "gage" is a tracer system developed for knitting yarns, but with a much broader application potential. It is of special interest in that it uses a tracer which is not radioactive when it is applied. This prevents contamination of the knitting machine.

The tracer, an antimony compound, is dissolved in the sizing wax, which is then applied to the knitting yarns in regular production. At intervals, samples are removed and exposed to a neutron source. This makes the antimony radioactive, so that it "takes its own picture" when exposed to an x-ray plate—producing an autoradiograph that shows exactly where it—and the wax—are distributed on the yarn.

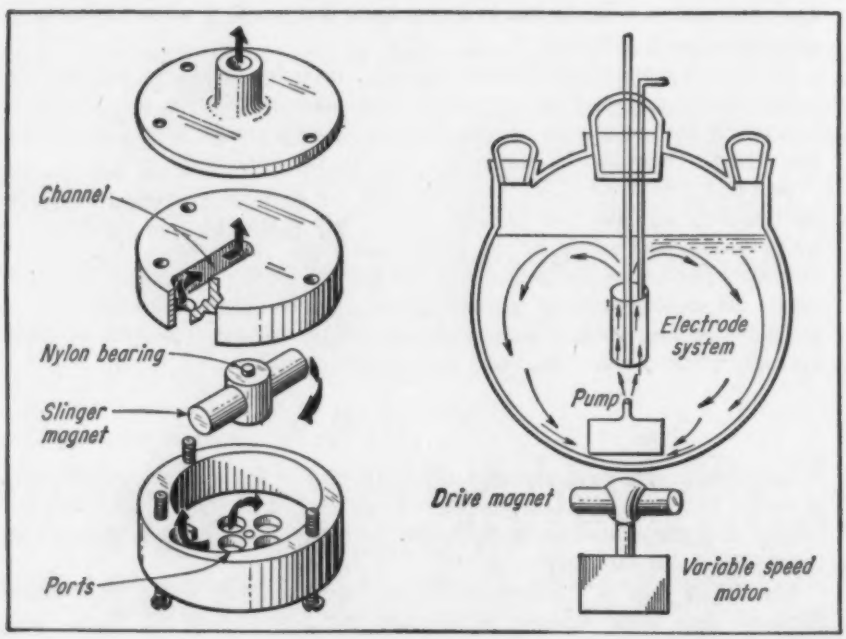
As NCL points out, conventional methods of analysis would not do the job because the samples are too small for easy handling, and many of the components of the wax are already present in the natural yarn.

(Note: More on engineering uses of radioisotopes in forthcoming issue.)

• • • •

An all-plastic magnetic pump that fits through a 2-in. glass joint and operates smoothly in refrigerated water close to the freezing point, has been designed at National Bureau of Standards.

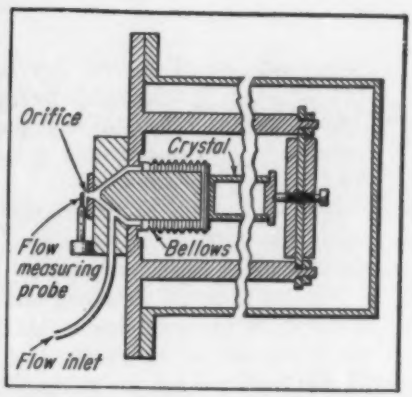
The pump is **of the centrifugal type,** using a commercial Teflon-covered bar magnet as the slinger (diagram at left). Fluid enters the pump through parts in the base, is impelled by the magnet, and redirected by the channel in midsection so it passes out the nozzle at the top. The slinger bar is driven by second bar magnet rotating on about a 1½ in. dia speed-controlled shaft outside of the glass container (diagram at right). Under these conditions, Mary Barnes and Ralph Noyce of NBS report in *Review of Scientific Instruments,* 700 cc/min can be circulated at 1200 rpm. NBS uses the system to provide a shaped jet of ultraclean fluid for electroprecipitation of barium-strontium carbonates on thermionic anodes. Screws and bearings are nylon; all other pump parts, Teflon.



Whisker-strengthened metals come closer to practical application as GE announces results of tests on whisker-reinforced silver. Tests with ultrafine tungsten wire have already shown that copper's strength can be trebled or quadrupled (*PE—Aug* 29 '60, *p* 9). Now GE researchers say they have been able to increase the strength of silver as much as five times by incorporating real "whiskers"—(the tiny near-perfect, elongated crystals that show tensile strengths far in excess of those obtained with normal materials. They're using alumina whiskers, in amounts to 10 or 15%, and believe that similar techniques applied to high-strength metals will produce materials "several times stronger at white heat than any high-strength alloy."

• • • •

A piezoelectric flow modulator that could be used for an input device in dynamic studies, is under test at NASA's Lewis Research Center. It's a device in which **a constant flow is changed to an alternating or rippled flow with relatively high-frequency oscillation.** It's been tested over a frequency range from 100 to 5000 cps at mean flow rates of 0.40 and 0.23 lb/sec; and, its designer says, it has a nearly flat amplitude response at frequencies below 600 cps. But there are sharp resonances and a general increase above that point.



As described by L. M. Wenzel of LRC, the device consists of **a 7½ in. tubular ceramic transducer** (1½ in. dia with a ⅛ in. wall), hooked up so a **change in applied voltage results in a change in axial length.** The transducer is clamped between a bellows and a cross beam (see diagram) in such a way that the change in length of the crystal is transferred to the bellows, creating a pumping action.

Liquid is introduced through small-dia tubing to reduce flow perturbations. The outlet is via two 0.10-in. orifices.

Tests thus far, indicate the system will be **useful where flow perturbations of low amplitude, high frequency, and fast response are required.**

• • • •

Inorganic adhesives that show mean tensile strengths of 5000 psi at 800 F, are relatively resistant to thermal shock, and are **"capable of sustained strengths at temperatures to 1500 F"** are reported by H. R. Thornton of U of Illinois.

These are **borosilicate glasses containing metal fillers and selected oxides;** and, Thornton says, they can be modified for optimum adhesion as well as high mechanical strength. He's prepared a report on their basic physical properties, thermal expansion, and other characteristics for presentation to the American Ceramic Society's Enamel Div this week.

• • • •

Urethane foams with controlled resiliency are being developed by Bendix Corp materials engineers. The Army's QMC Research & Engineering Command is working on **controlled-density** materials that can be foamed at temperatures as low as —40 F.

These are only two of many recent developments that promise to make these foamed plastics even more useful as insulating and structural materials.

At the ACS Chicago meeting, C. H. Smith of Bendix (Kansas City) described a new approach to urethane formulation that has produced **materials with compression-set values ranging from 6 to 112%** under similar conditons; and load

deflection values that vary by as much as 700%. The method: varying the isocyanate component. This way, Smith has produced materials which give load deflection values ranging from 6.5 to 25.5 psi at room temperature and 4.7 to 27.7 psi at 165 F.

The Army's newest foams are **polyurethane-vinyl copolymers,** catayzed by ionic components which, Dr. George R. Thomas of Natick reports, have made it possible to produce **foamed** structural components **at ambient temperatures of 20 F, and,** in some cases, **even at —40 F;** and, he says, they show high compressive strength.

• • • •

Columbium, vanadium, and their sister metals tantalum and titanium are scoring new records in strength and endurance as a result of alloy and process development. Recent months have seen announcement of tantalum alloys that retain their strength at high temperatures (*PE—Aug* 14, *p* 14) and improved performance for titanium (*PE—Sep* 4, *p* 9).

Now, Bureau of Mines reports on electro-refining studies of **vanadium** that promise better metal **at lower cost.** New techniques are producing metal **with a ductility which rivals that made by** the **costly iodide process.**

The metal is not as strong and hard as calcium-reduced material, but it is higher in both respects than iodide titanium. Cold-worked metal showed ultimate tensile strength in the 61,300 to 82,400 psi, with yield strengths ranging from 58,600 to 78.900 psi, and elongation (in one in.) from 4.9 to 12.5%.

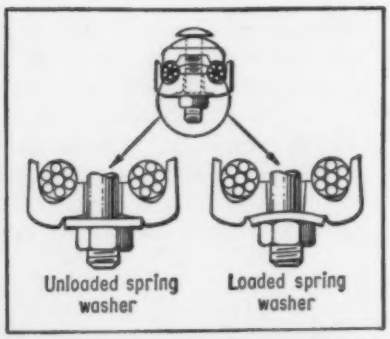
As to **columbium,** Defense Metals Information Center relays recent reports from Temescal and Westinghouse which indicate that **strength and oxidation resistance can** both **be improved** by addition of tungsten, tantalum, and molybdenum.

The Cb—10Ta—10W alloy is particularly promising. At 2400 F, it was found to be "at least as resistant to oxidation as any alloy now available."

Also showing up well in early tests are columbium- hafnium and columbium-zirconium alloys. Westinghouse reports that the Cb-Hf and Cb-Zr alloys posses good low-temperature ductility and very high recrystallization temperatures.

• • • •

A design system that will **permit use of bolted connectors** on aluminum conductors **and get around** the problem posed by **cold flow** is outlined by G. L. Flynn and T. L. Rundlett of Anderson Electric. The system is a simple one: **insertion of a flat spring washer** in the lower connector component (see diagram).



As Flynn and Rundlett told the AIEE Pacific General Meeting, one of the most acute to the electrical connector problem is the dimensional change or "relaxation", that occurs in all connections involving aluminum conductors. It is caused by the uncontrolled cold flow of the aluminum when under the influence of connector pressure.

Compression connectors can get around the problem. But bolted connectors are cheaper; and preferable in many cases. And, Flynn and Rundlett chaim, the spring washer permits their use.

The washer is inserted in a prepared recess in the bottom connector. It dishes around the fulcrum as the nut advances, and seats itself against the tapered surface, which protects it against overstressing. **—ARG**

PRODUCT
ENGINEERING

How to design

Rocking mechanisms

Graphical method shows how to design "waltzing pairs" that roll without sliding. A family of logarithmic spirals gives optimum transmission angles.

KURT HAIN, Institute for Fundamental Research, Brunswick, Germany
Translated by F R Erskine Crossley, Yale University

THE OBJECTIVE is to have an output member oscillate through a limited arc or back and forth along a straight line. Normally you would think of cams or four-bar linkages but a rocking mechanism may be the best choice. A rocking mechanism consists of two conjugate surfaces in continuous contact and having only relative rolling motion. This is the main advantage because rolling friction suffers smaller energy losses and wear than sliding friction.

A pair of rocking levers can be compared to the rolling action of the centrodes of any four-bar linkage. They can be used to guide a point, pin or pivot along a desired curved path; or to transmit a rotation from one shaft to another with a desired and varying angular velocity ratio. Graphical layout for each has its own details.

Waltzing pair for a point-path

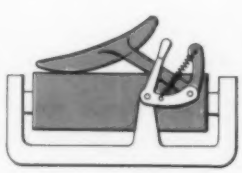
This is similar to coupler-curve problem, and it involves three curves —the desired point-path, and the two rocking surfaces. When any two are known, the third can be found by layout.

Assume that the two conjugate surfaces, a and b, are known, Fig 1 (A), and it is desired to find the form of the coupler curve α which will actuate the waltzing pair without sliding, when connected at point E. The layout is as follows:

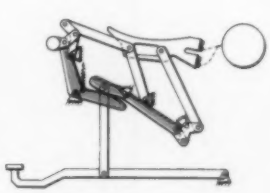
Starting from point P_1 and its mating point Q_1, the two surfaces are

Typical rocking mechanisms

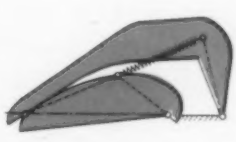
Sensitive contact gage uses a rocking pair to decrease the effect of friction and increase the accuracy.



Variable electrical resistor has a rocking surface instead of a sliding brush to reduce wear with smooth operation.



Typewriter linkage has a rocking pair that actuates upper or lower case letters with smoother, quieter action.



Rocking mechanism derived from 4-bar linkage has constant spring length which transmits no force to bearing.

divided into a convenient number of equal arcs:

$P_1P_2 = Q_1Q_2,\ P_2P_3 = Q_2Q_3$, *etc.*

Then a series of arcs are drawn, the first with center P_1 and radius Q_1E, the next with center P_2 and radius Q_2 E, etc. The path a of point E is the envelope curve tangent to the outside of arcs k_1, k_2, etc.

Or suppose coupler curve α and the surface b are known, and it is desired to establish surface a, Fig. 1(B). First, divide the surface b into a convenient number of equal arcs, the same as above. Next, draw arc r_2 passing through point Q_2 with center P_1, and on this are r_2 find the point P_2 which would be the center of an arc k_2 of radius Q_2E tangent to curve α. Similarly, draw arc r_3 *from center* P_2 with radius Q_2Q_3, and P_3 is found on this arc such that arc k_3 tangent to curve α can be drawn from it with radius Q_3E.

The third case, Fig 1(C), with coupler curve α and surface a known, the surface b is found in a manner analogous to the second case above. It is illustrated here to show that two surfaces and the coupler curve can assume a variety of shapes. The four-bar linkage that will generate the desired coupler curve α can be found by several well known methods.

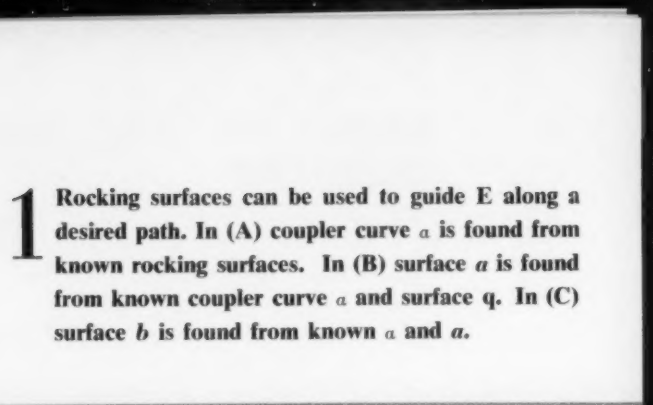
Oscillations from one shaft to another

Sometimes it is desirable to transmit an oscillating motion from one shaft to another as in Fig 2 (A). To do this with two rolling surfaces the

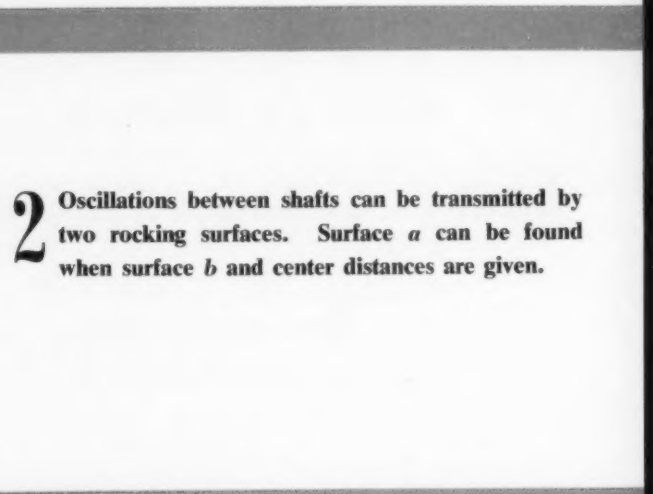
text continued, page 68

Symbols

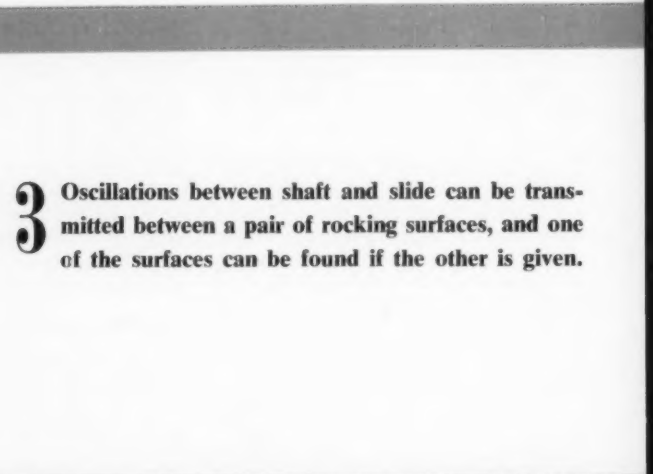
a,b	—*Rocking surfaces, or in certain figures projected distances.*
A,B	—*Surface centers of rotation*
i	—*Velocity ratio*
k,q,r,s	—*Arcs, or in certain figures projected distances.*
m	—*Effective radius*
M	—*Turning moment*
P	—*Force*
Q,R, etc.	—*Points on the surfaces*
v	—*Velocity*
$x_0 = r_0/AB$	*where* r_0 = *Distance of instantaneous center from one pivot point, and* AB *is distance between pivot points.*
$\mu\ \phi\ \psi$	—*Angles*
ω	—*Angular velocity*



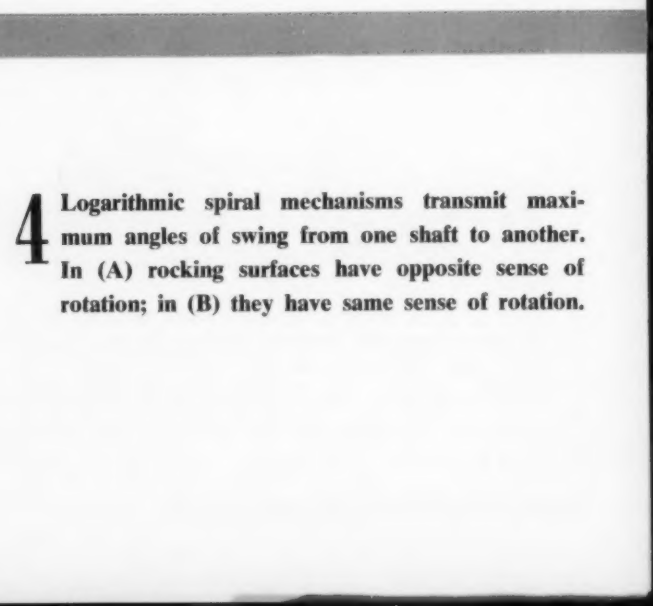
1 **Rocking surfaces can be used to guide E along a desired path. In (A) coupler curve α is found from known rocking surfaces. In (B) surface a is found from known coupler curve α and surface q. In (C) surface b is found from known α and a.**



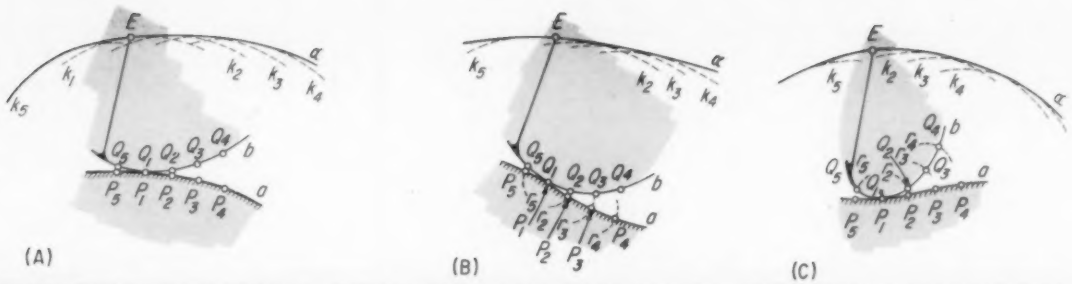
2 **Oscillations between shafts can be transmitted by two rocking surfaces. Surface a can be found when surface b and center distances are given.**

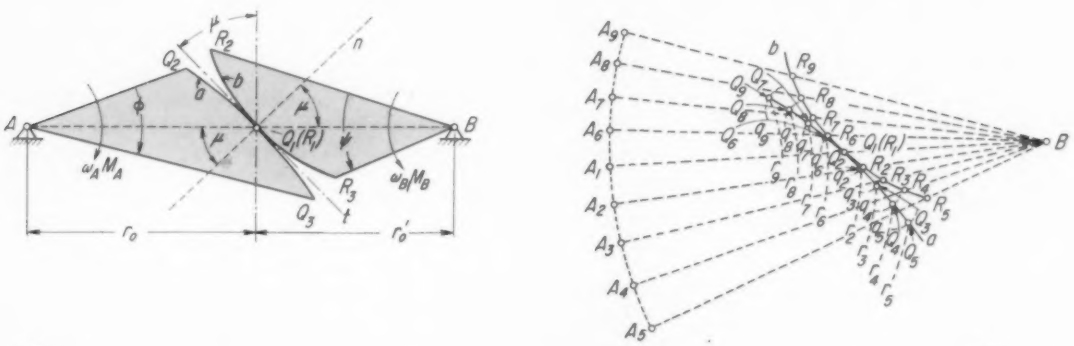


3 **Oscillations between shaft and slide can be transmitted between a pair of rocking surfaces, and one of the surfaces can be found if the other is given.**



4 **Logarithmic spiral mechanisms transmit maximum angles of swing from one shaft to another. In (A) rocking surfaces have opposite sense of rotation; in (B) they have same sense of rotation.**


E
a
b
(A)
(B)
(C)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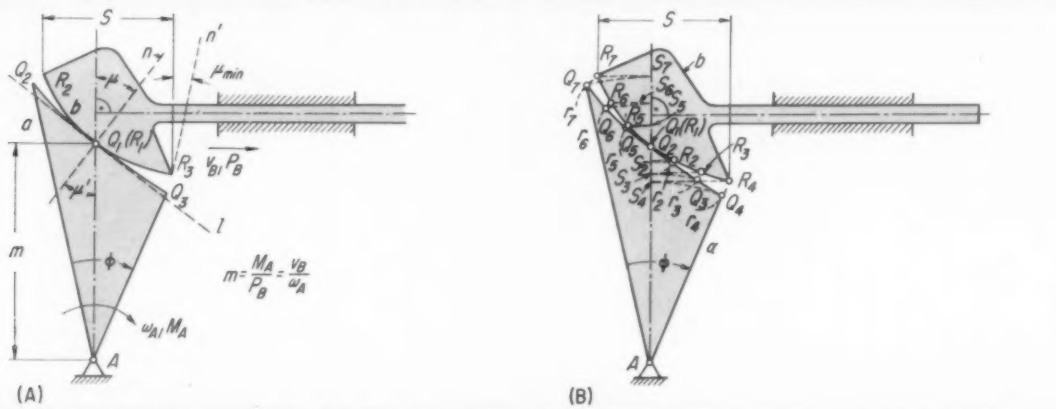
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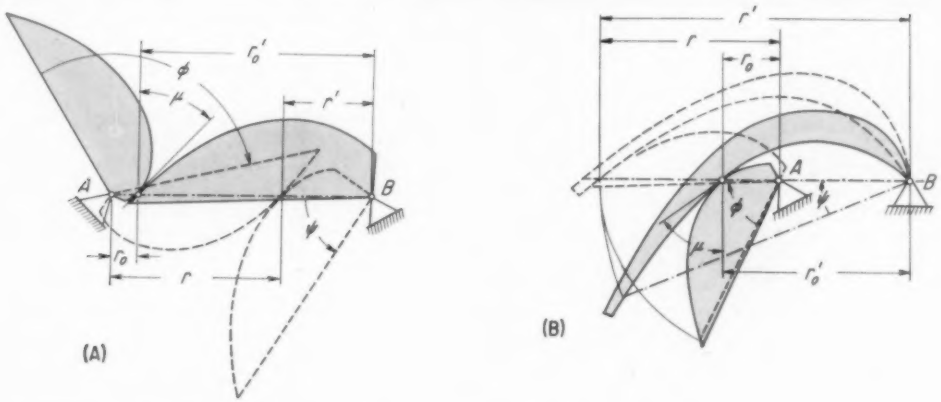
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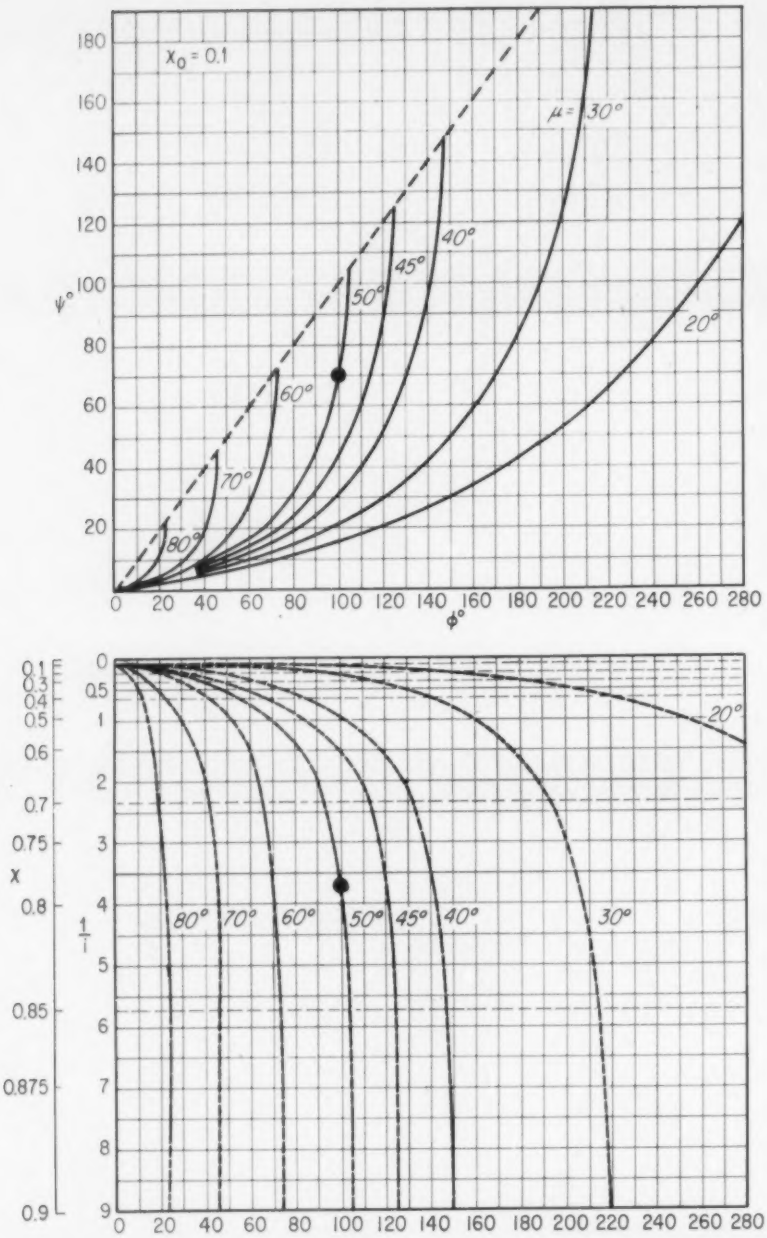
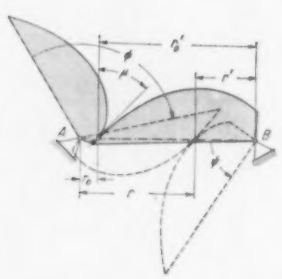
(A)
(B)



5 **For maximum transmission angles** between two shafts, rocking pair should be shaped in logarithmic spirals. Here are the most favorable pressure-angle relationships for a pair with opposite senses of rotation.



instantaneous contact point of the two curves must always lie on the line of centers AB. Another important point is that pinching of the curved surfaces must be avoided. This is a factor that is governed by the pressure angle μ, which is defined as the angle between the common normal n and the line between centers AB.

Thrust transmission between a pair of rocking curves is best when $\mu = 90°$, and conversely it is impossible when $\mu = 0°$ (Friction wheel drives work effectively when $\mu = 0°$. However, in the case of rocking mechanisms minimum friction is desired, and this means that the pressure angle must be as near to 90° as possible. The important difference is that in a rocking pair the normal pressure is the transmitting force, while in a friction wheel the frictional force is the motivation.) With spur gears the velocity ratio is inversely proportional to the ratio of pitch radii. This same ratio is applicable to rocking levers where the angular velocities are inversely proportional to the distances of the instantaneous points of contact from rotation centers. Because the angle μ is never 0°, the contact point moves and the velocity ratio must vary. Thus it is not possible to transmit a motion with a constant velocity ratio with rocking levers.

Neglecting frictional losses the velocity ratio can be written in terms of the torque ratios:

$$i = \frac{\omega_A}{\omega_B} = \frac{M_B}{M_A}$$

where torque M_B in shaft B balances torque M_A in shaft A.

In order to fulfill the basic requirement that the instantaneous contact point of the two surfaces always be in the line of centers AB, the two surfaces must be conjugate and of equal length. When one of the surfaces and the shaft center positions are known, the mating surface can be found by the so-called "kinematic inversion" described above in connection with Fig 1. The over-all turning angles ϕ and ψ of the two bodies are the angles between the lines joining the end points of the surfaces and the shaft centers A and B.

In Fig 2(B) the surface b and the distances to A and B are given. An arc through A is drawn from center B, and it is divided into convenient lengths such as A_1A_2, A_2A_3, etc. Rays are then drawn to B which intersect known surface b at points R_1 to R_5. A series of arcs q are drawn from center points Q on a using successive radii, R_2R_2, R_3R_4, etc.; and another series of arcs r are drawn from center points A using successive radii A_2R_2,

A_3R_3, etc. The intersection points of these two series of arcs is the locus of the desired surface *a*.

Oscillations from a shaft to a slide

Oscillating motions of a shaft can also be transmitted to or from a reciprocating rod by a rocking mechanism. Here the sliding body is considered as turning about a centerpoint at infinity. The pressure angle μ, Fig 3(A), is the angle between line *n* normal to both curved surfaces at the instantaneous point of contact Q_1 and a line from *A* perpendicular to the axis of the sliding body. Minimum pressure angle μ_{min} occurs when point R_3 is in contact with the mating surface. This also applies to the previous example.

The total rocking angle ϕ is the angle between the lines joining the end points of surface *a* and shaft center *A*, and the corresponding stroke *s* of the sliding member is the horizontal projection of surface *b*. The "effective radius" *m*, Fig 3(A), is the ratio of slider velocity v_b to angular velocity ω_a of the rocker; it is equal to the ratio of the rocker turning moment M_A to the slider force P_B:

$$m = \frac{v_B}{\omega_A} = \frac{M_A}{P_B}$$

Graphical methods can be used to find either surface when the other is given along with the distance of A from the slider axis. In this case, Fig 3(B), the slider surface is given. It is divided into a number of convenient segments marked with R_1 to R_7. From these *R* points, horizontal lines are drawn to intersect the vertical axis at points S_1 to S_7. Next, one series of arcs are drawn from each *Q* point, using R_1R_2, R_2R_3, etc. as radii; another series of arcs are drawn from *A*, using AS_1, AS_2, etc. as radii. The intersection points of the respective arcs forms the desired surface *a*.

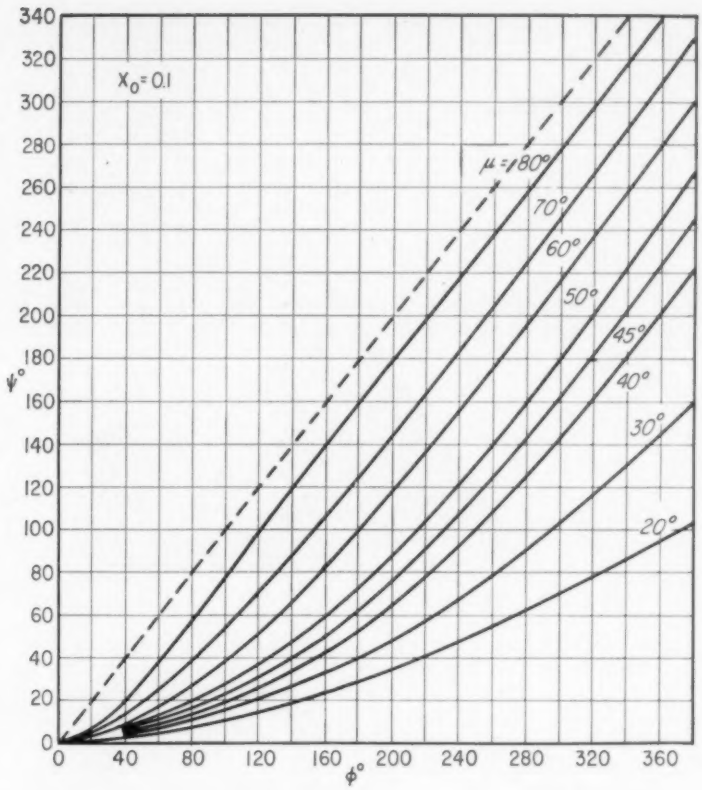
Logarithmic spirals as rocking pairs

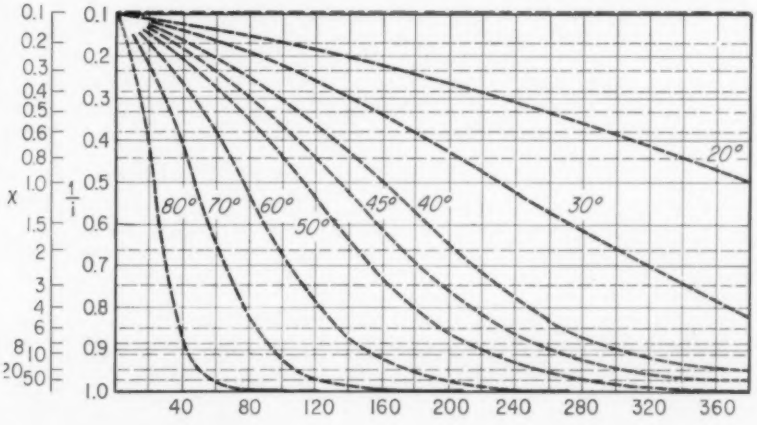
When it is necessary to transmit as large an angle as possible from one shaft to another, it is recommended that logarithmic spirals be used as the rocking surfaces. These always have a constant angle of slope which, used in this way, becomes the pressure angle of the pair.

Assume the contact point of the rocking surface is to be near one pivot point so that (Fig 4)

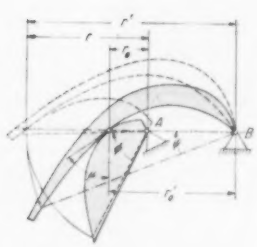
$$x_0 = r_0/AB = 0.1 \text{ (minimum)}$$

Then the most favorable transmission angles in relation to the angles of swing are given Fig. 5 & 6. The curves in Fig. 5 are for a rocking pair with opposite sense of rotations as in Fig

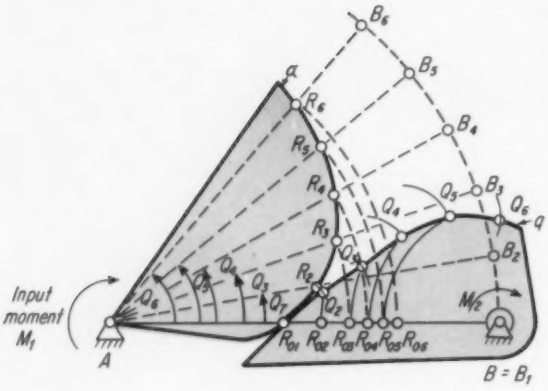




6 **For same direction of rotation** (rocking pair made in logarithmic spirals) these pressure-angle relationships are best. Note that in this case both shafts may turn through larger angles—approaching a full revolution.



EXAMPLE



It is desired to design a pair of rocking surfaces having opposite sense of rotation and generating the functional relation $y = x^3$. Range of operation for x is from 0.4 to 1.4 with a scale of $x = 0.2$ to correspond to a 10° angular shift. Distance between centers AB (see left) is to be 5 in.

Solution

The derivative of the given function is $dy/dx = 2x$, and this must also be the reciprocal of the velocity ratio:

$$dy/dx = 1/i = r_0/r'_0, \text{ as per Fig 2(A)}$$

In this case $r_o + r'_o = 5$ in. so,

$$r_0 = \frac{(5/i)}{\left(1 + \frac{1}{i}\right)}$$

Solution of the above equation can be put in tabular form shown below, and then used to lay out surface a.

The procedure is as follows: on AB lay off the distances $AR_{01} = r_{01}$, $AR_{02} = r_{02} \ldots AR_{06} = r_{06}$, and then find points R_2 through R_6 by swinging arcs around center A through the points R_{01} to R_{06} to intersect rays from A drawn at the station angles $\phi_{12} = 10°$, $\phi_{18} = 20° \ldots$ $\phi_{16} = 50°$. These rays are extended to arc B_1B_6.

The second surface q is found as follows: Draw arc with a radius $R_{01}R_2$ from center R_{01} to intersect at Q_2 an arc with a radius B_1R_{02} drawn from center B_1. Second point Q_3 is found at intersection of arc with radius R_2R_3 from center Q_2 and the arc with radius B_1R_{03} from center B_1. Third point Q_4 is found at intersection of arc with radius R_3R_4 from center Q_3 and the arc with radius B_1R_{04} from center B_1. Similarly, points Q_5 and Q_6 are found to complete the surface.

Mechanism Station	x	$y = x^3$	$dy/dx = 2x$	r_0 in.
1	0.4	0.16	0.8	2.22
2	0.6	0.36	1.2	2.73
3	0.8	0.64	1.6	3.08
4	1.0	1.00	2.0	3.33
5	1.2	1.44	2.4	3.53
6	1.4	1.96	2.8	3.68

4(A); curves in Fig 6 are for rocking pair with the same sense of rotations as in Fig 4(B).

For example, let input angle $\phi = 100°$ and driven angle $\psi = 70°$ with opposite sense of rotation, then from Fig 5 the best pressure angle $\mu = 50°$. The relative position of the contact point of the surfaces can vary from $x_o = 0.1$ to $x = 0.78$ of the distance between pivots.

Assume another rocking pair with same sense of rotation, and angles $\phi = 140°$, $\psi = 90°$. Fig 6 gives $\mu = 70°$, and the position of the contact point on the rocking surfaces can vary from $x_o = 0.1$ to $x = 50$. At the same time the ratio 1/i varies from 0.1 to 1.0.

For **reprint** of above article, just check 614 on one of the Reader Service cards found in this issue.

Editor's Note: This article was taken from the text for the Refresher Course in Mechanism 1959/1960, arranged and sponsored by the Chamber of Commerce & Industry of the City of Brunswick, Germany, in cooperation with the Division of The Science of Mechanism of the Society of German Engineer (VDI). Course director: Kurt Hain. For other articles on four-bar linkages:

Simpler Acceleration Analysis of Low-Complexity Mechanisms, May 8 '61, p 26—Gives a simple offshoot of the relative-acceleration method.

When Linkages Need Harmonic Analysis, Mar 6 '61, p 47—Gives tabular solution to complex Fourier-series equations and thus simplifies harmonic analysis for efficient design of crank-and-rocker mechanisms.

Special Chart Leads You to Four-bar Linkage Proportions, Sep 19 '60, p 76—With two points given, this handy chart quickly locates the other two. You find the proportions of all four bars without cumbersome mathematics or graphical methods.

Graphical Methods for Designing Four-bar Linkages, Apr 4 '60, p 37—Gives roundup of methods used to synthesize four-bar linkages, including the point position reduction method developed by Kurt Hain.

Robert's Law Helps You Find Alternative Four-bar Linkages, Oct 27 '58, p 54—Method of similar triangles is expanded by author's method of laying off the link lengths along a straight line.

Linkage Design Techniques, Dec '54, p 133—Gives comparison of four methods—two approximate and two exact—for construction and design of four-bar linkages.

—Frederick Marich

PE special report on

Today's fluid lubricants

Comparison data of oils, synthetics, greases, additives; recommendations for mechanical components; solids and gases for high temperatures.

NICHOLAS P CHIRONIS, associate editor

LUBRICANTS are called upon today to perform under mechanical and environmental conditions unheard of a few years ago. To meet this demand, the performance capabilities of petroleum oils, synthetics, and greases —which comprise the fluid-lubricant group—are continually being boosted by new refining techniques, additives and base stocks.

Ingredients and production techniques employed by lubricant manufacturers in their products, however, are shrouded under a cloak of proprietary secrecy. There are innumerable basc stocks and additives in existence today. These are compounded together in specialized ways to produce the final product. The user may be able to obtain specific details on a product—failing this, however, he can request information on the general class or additive employed. Such information is generally obtainable. This gives him a good clue to the potentialities of a product.

This article covers basic types of oils, greases and additives and compares them as to performance, recommended applications and cost. A special section on high-temperature lubricants includes data on solids and gases employed for lubricants.

PETROLEUM AND ORGANICS

Petroleum (mineral) oils still form the largest class of lubricant in common use. They are extracted from crude oil of various parts of the world. The crudes differ quite markedly from one well to another and in the refining process, but can broadly be separated in two groups—paraffinic oils and naphthenic oils. The division is based on the way hydrogen and carbon atoms link together.

Paraffinic oils are relatively stable at high temperatures. They also have a high viscosity index in that they show less change in viscosity with temperature. But they contain a high proportion of dissolved wax, hence tend to solidify at higher temperatures than do the naphthenic oils.

Naphthenic oils are less stable at high temperatures but have little or no wax and therefore remain liquid at low

Blotter test quickly checks ability of oils to handle dispersion and contamination. Test can be conducted by user in the field. It is simple to interpret and inexpensive to use. The test can also check for alkalinity—a property added to oils to reduce wear caused by acid action. Samples shown are diesel lubricating oils. *Shell Oil Co*

Lab samples of calcium-complex EP grease mixed and milled on Pyrex sheet. This new class is finding wide use in heavy-duty gearing. *Socony Mobil Oil Co.*

Synthetic lubricants ...

	VOLATILITY	VISCOSITY-TEMPERATURE CHARACTERISTICS	OXIDATION RESISTANCE	LUBRICITY	THERMAL STABILITY	HYDROLYSIS RESISTANCE
DIBASIC-ACID ESTERS	Generally lower than petroleum oils	Good to excellent	Fair to good	Fair to good	Fair to good	Fair to good
PHOSPHATE ESTERS	Generally lower than petroleum oils	Fair to good	Good to excellent	Good to excellent	Poor to fair	Poor to good
SILICONES	Much lower than petroleum oils	Excellent	Excellent	Poor to fair	Fair to excellent	Excellent
SILICATE ESTERS	Lower than petroleum oils	Excellent	Poor to fair	Fair	Good	Poor to fair
POLYGLYCOL-ETHER COMPOUNDS	Approximately equal, some lower than petroleum oils	Good to excellent	Poor to fair	Good	Fair to good	Fair to good
FLUOROCARBONS	Some lower, some higher than petroleum oils	Very poor	Excellent	Poor to excellent	Excellent	Excellent
POLYPHENYL ETHERS	Much lower than petroleum oils	Poor to fair. Generally high melting points	Fair to good	Fair to good	Good to excellent	Fair to good
SILANES	Much lower than pet oils	Good to excellent	Poor to fair	Poor to fair	Good to excellent	Good

temperatures. But their viscosity index is poor (low).

Pennsylvania crude are rich in paraffins; Gulf Coast (California) crudes in naphthenes. Modern refining methods have largely wiped out the distinction between crudes, and many products today employ a mixed-base stock which is a mixture of naphthenic and paraffinic oils. Today, there is no exact line of distinction between, say, a paraffin-base oil and a mixed-base oil.

Organic (fixed) oils are extracted from animals and vegetables. They were at one time the only lubricating fluids known. Their chief uses today are in the manufacture of greases, and as compounding agent in mineral oils. They offer additional protection in case of inadequate oil supply, and

OIL vs GREASE—A quick comparison

Key assets of an oil:
- Carries away heat better
- Does a better job at high speeds
- Does a better job at high operating temperatures
- Easier to drain and refill
- Usable at many points in a machine
- Carries away dirt, water and wear products

Use an oil when:
- Speeds are extremely high
- Operating temperatures are consistently high
- Dirt conditions are not excessive
- Oiltight seals can be employed
- Centralized system are available for other machine parts

Key assets of a grease:
- Requires less maintenance; regreasing is infrequent
- Dripping and spattering is avoided
- Does a better job of sealing against dirt, dust or water
- Less expensive seals required for bearings
- Allows more flexibility in bearing position
- Assures some lubrication even when bearing is neglected
- Minimizes danger of rust when bearing is not in use
- Sometimes reduces noise and vibration

Us a grease when:
- Temperatures are not excessive
- Speeds are moderate
- Protection is required from dirt, fumes or other contaminants
- Elaborate bearing enclosures are to be avoided
- Extended operation without maintenance is essential

performance, price and applications

FIRE RESISTANCE	SOLVENT EFFECTS ON PAINTS, RUBBER, ETC.	RESISTANT MATERIALS AVAILABLE?	SOLUBILITY IN PETROLEUM AND OTHER SYNTHETICS	IMPROVEMENT ADDITIVE COMPATIBILITY	PRICE RANGE PER GALLON	TYPICAL APPLICATIONS
Poor to fair	Pronounced effects	Some	Good to excellent	Generally good	$3.00-10.00	Instrument oils, low volatility grease bases, special hydraulic fluids, jet turbine lubricants.
Good to excellent	Pronounced effects	Yes	Good to excellent	Generally good	$4.00-12.00	Fire-resistant hydraulic fluids, low-volatility high-lubricity grease bases, lubricity additives in other synthetics, special low-temperature lubricants.
Poor to good	Generally small effect	Yes	Poor	Poor	$20.00-40.00	High-temperature bearings, condensation pump lubricant, low-volatility grease base for lightly loaded bearings, damping fluids, devices requiring minimum viscosity change with temperature
Poor to fair	Some effects	Yes	Fair to good	Fair to good	$8.00-20.00	Heat transfer fluids, high-temperature hydraulic fluids, low-volatility, low-viscosity grease bases. Components for low-viscosity hydraulic fluids.
Fair to good	Pronounced effects on paint. Small effects on rubber	Some	Fair to good	Generally good	$2.00-6.00	Synthetic engine oil, special hydraulic fluids, forming and drawing lubricants, low-temperature grease bases, vacuum-pump lubricants, component of other synthetic lubricant formulations.
Excellent	Practically none	—	Very poor	Poor to nil	$100-225	Nonflammable, extreme oxidation-resistant lubricant for plant processes or devices handling reactive materials. Heat-transfer fluid.
Poor to fair	Some effects	Yes	Fair	—	Over $100	High-temperature fluid for reactor coolant, hydraulic applications at very high temperature. Applications not yet fully developed.
Fair to good	Generally small effects	Yes	Poor	Poor	—	Base stocks for high-temperature greases, hydraulic fluids and engine lubricants. Require extensive formulation.

Source: D H Moreton, Synthetic Fluids Service, Inc., Pacific Palisades, Calif.

form stable emulsions with water that have good lubricating qualities.

SYNTHETIC LUBRICANTS

The need of industry and of the military for lubricants to perform satisfactorily at conditions too severe for petroleum lubricants has led to the development of synthetic lubricants. These may be defined as viscous fluids manufactured from chemical raw materials, generally chemical compounds other than hydro-carbons. Some synthetic lubricants, however, are derived from hydro-carbons modified by reaction with other compound or with other elements, such as fluorine or chlorine.

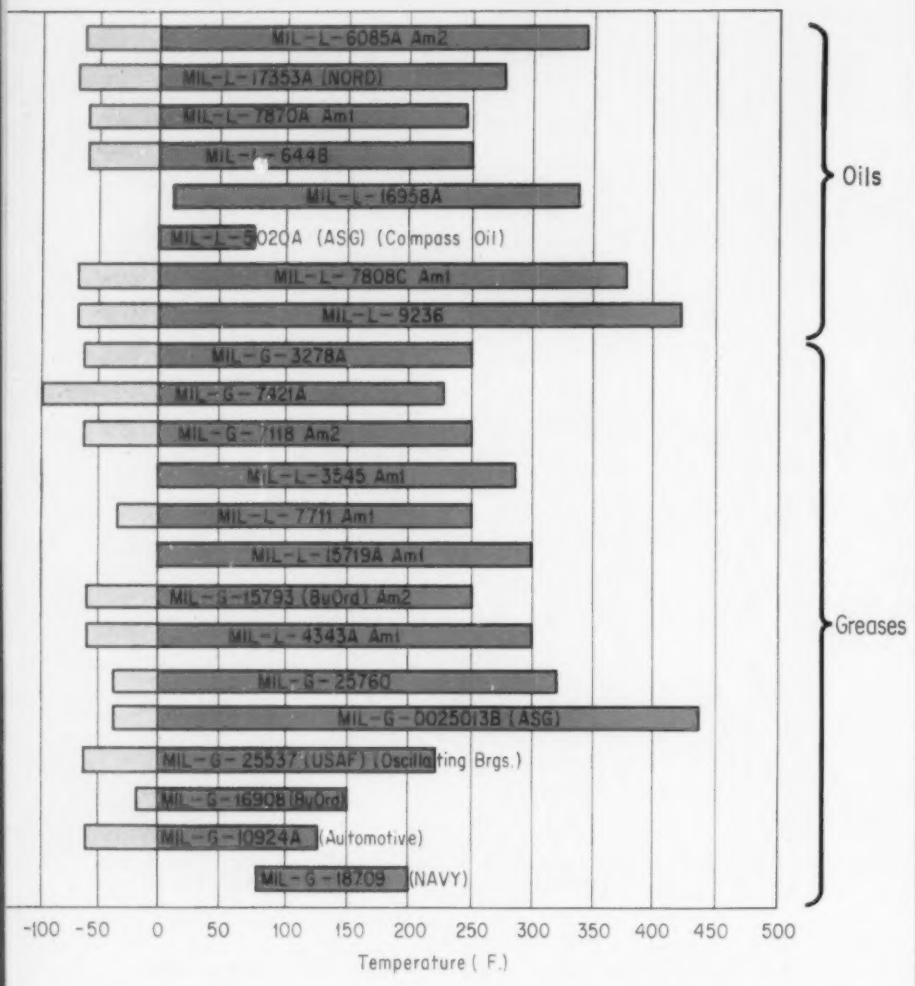
Synthetic lubricants are classed according to their distinguishing chemical source, as for example, the silicones.

Some common names for synthetic lubricants

Chemical class	Common name
Dibasic-acid esters	MIL-L-6085A aircraft instrument oil MIL-L-7808 jet engine oil MIL-L-6387 hydraulic fluid
Phophate esters	Less flammable aircraft hydraulic fluid
Silicone	Dow Corning 200, 500 or 700 General Electric Versilube F50
Silicone esters	MIL-H-8446 hydraulic fluid
Polyglycol ethers	Ucon lubes
Flurocarbons	Nonflammable fluids containing fluorine and carbon
Chlorinated hydrocarbons	Aroclor
Polyphenyl ethers	Experimental high-temperature hydraulic fluid
Silanes	Experimental high-temperature fluid containing silicone

Source: M R Fenske and E E Klaus, Chemical Engry Dept, Pennsylvania State U, University Park, Penna.

Temperature range for military specs on lubricants



Source: New Hampshire Ball Bearings Inc, Peterborough, N.H.

There is a wide variety of synthetic lubricants in each class. The table on p. 72, lists today's popular synthetics and compares them on the basis of performance capabilities, price range and typical applications. The prices noted are applicable only to the more widely used members of each class as base-stock materials. They should not be compared with finished fluids or trade formulations. Common names for some of the synthetics are also given on this page.

A comparison of synthetic lubricants with petroleum oils, p. 74, shows that in general, synthetics have superior properties but are more costly. The cost figures are the number of times greater in cost than petroleum oils at a typical base price.

Here is a rundown of the key characteristics of eight synthetic lubricants:

Dibasic acid esters (diesters)

This is one of the most promising synthetics. Exact identities of compounds contained in commercial products are kept under proprietary secrecy, but many of these lubricants are made from animal or vegetable oils as raw materials, others from petroleum hydrocarbon synthesis. One widely used member of this family is di-e-ethyl hexye sebacate, marketed under several trade names.

Diesters have excellent viscosity-temperature properties, low volatility and freezing points. They are high in chemical solvency and readily accept additives such as lubricity and viscosity-index improvers. This thermal stability, while not the equivalent of pure hydrocarbons is still very good They blend readily with many other classes of synthetics to improve their properties.

Dibasic acid esters are finding widespread application in low-volatility

Synthetic lubricants

	VOLATILITY	VISCOSITY-TEMPERATURE CHARACTERISTICS	LUBRICITY
DIABASIC-ACID ESTERS	better (than pet. oils)	much better	better
PHOSPHATE ESTERS	better	slightly better	much better
SILICONES	much better	outstanding	much worse
SILICATE ESTERS	better	much better	similar
POLYGLYCOL ETHER COMPOUNDS	similar	better	better
FLUOROCARBONS	worse	much worse	much worse
CHLOROCARBONS	similar	worse	slightly better
POLYPHENYL ETHERS	much better	similar	similar

greases, low-temperature instrument lubricants, high-temperature gas-turbine lubricants, and in special high-viscosity hydraulic oils.

Phosphate esters

These lubricants vary widely in most of their properties except for their lubricity, which is generally high. Some are employed as "oiliness" or extreme-pressure additives in petroleum and other lubricants. Many members of this class have excellent fire-resistant properties.

Other advantages are high oxidation resistance, good compatibility with most other synthetic lubricants, lower volatility than petroleum oils.

Limitations—poor thermal stability at temperatures above 300 F, and high chemical activity which causes solvent action on most paints, plastics and rubbers.

Silicones

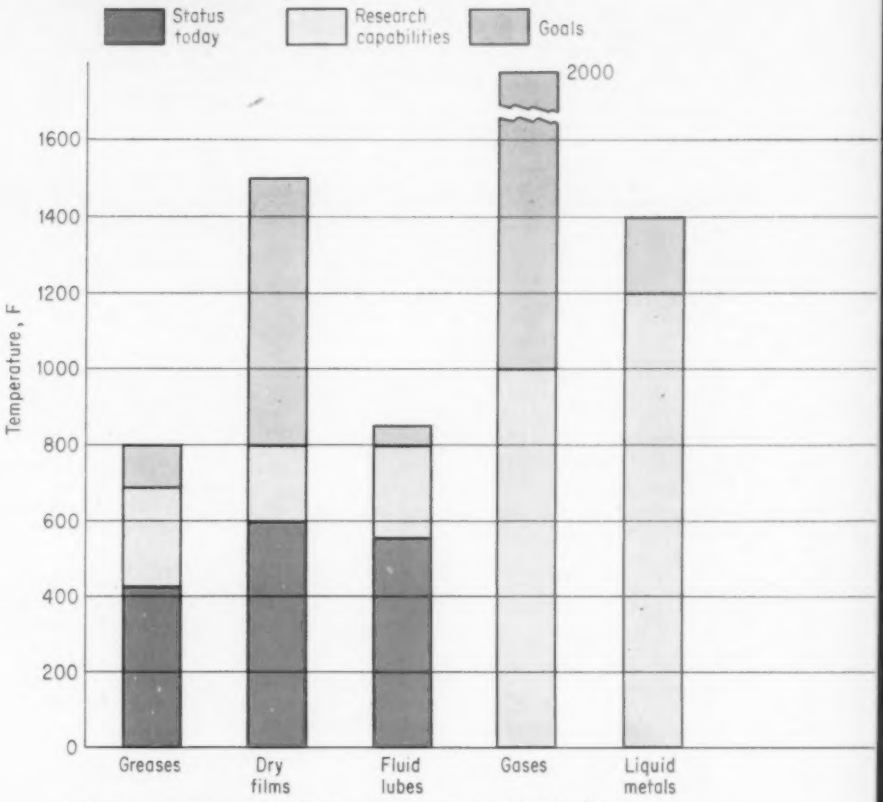
The name "silicones" has been broadly applied to fluids which are methyl-siloxane, phenyl-siloxane or methyephenyl-siloxane polymers. Silicone lubricants are available in a wide range of viscosities, from 35 SSU at 100 F to semiliquid greases. They are among the most expensive of the commonly used synthetics.

Main advantage over petroleum oils is their very high viscosity index (usually in the 200 range), their very low volatility and their high resistance to oxidation and hydrolysis. Thermal stability of most silicones is at least as good as that of petroleum oils. They do not affect most plastics, synthetic and natural rubbers.

On the debit side, they lack good lubricity. They do not readily wet most bearing metals—steel least of all. Only lubrication at high loadings, or of metal surfaces other than steel, is advisable. Available additives are effective in improving silicone lubricity but very little else. In fact, silicones are incompatible with practically all additives, and are immiscible with most other lubricants, petroleum or synthetic. Recent lists, however, indicate that silicones and diesters have better lubrication properties than either silicones or diesters used alone.

In spite of this drawback, silicones are finding increasing use in rolling-element bearings operating at temperatures to 350 F, and in applications requiring minimum viscosity change with temperature. In grease form, they

Potentials of high-temperature lubricants



Source: Air Force-Navy-Industry Conference, WADC TR 59-244

compared with petroleum oils

THERMAL STABILITY	SOLVENT EFFECTS ON RUBBERS	FLAMMABILITY	CORROSIVITY TO METALS	COST IN MULTIPLES OF PETROLEUM OILS
slightly better	worse	similar	similar	10 to 30
worse	much worse	better	slightly worse	5 to 40
slightly better	better	much better	similar	100 to 200
better	similar	similar	similar	30 to 40
slightly better	similar	similar	similar	5 to 20
better	much better	much better	much better	500 to 1600
better	much worse	much better	worse	10 to 20
better	better	similar	similar	500+

Source: R W Morton and H I Fuller, Esso Research and Engrg Co, N Y

These additives for additional

ADDITIVE	COMPOUNDS	PURPOSE
Oiliness, film strength, extreme pressure (EP) and anti-wear agents	Organic compounds containing chlorine, phosphorus and sulfur such as chlorinated waxes, organic phosphates and phosphites such as tricresyl phosphate and zinc dithiophosphate, and lead soaps such as lead naphthenate.	Reduce friction, prevent galling, scoring and seizure. Reduce wear.
Pour-point depressants	Wax alkylated naphthalene or phenol and their polymers. Methacrylate polymers.	Lower pour point of lubricating oils.
Viscosity-index improvers	Polymerized olefins or iso-olefins. Butylene polymers, methacrylic acid ester polymers, alkylated styrene polymers.	Lower rate of change of viscosity with temperature.
Foam inhibitors	Silicone polymers.	Prevent formation of stable foam.
Anti-oxidants or oxidation inhibitors	Organic compounds containing sulfur, phosphorus or nitrogen such as organic amines, sulfides, hydroxy sulfides, phenols. Metals like tin, zinc or barium often incorporated.	Prevent varnish and sludge formation on metal parts. Prevent corrosion of alloy bearings.
Anti-corrosives—corrosion preventives or catalyst "poisons"	Organic compounds containing active sulfur, phosphorus or nitrogen such as organic sulfides, phosphites, metal salts of thiophosphoric acid, and sulfurized waxes.	Prevent failure of alloy bearings by corrosive action. Prevent corrosive attack on other metal surfaces.
Detergents	Metallo-organic compounds such as phosphates, phenolates, sulfonates, alcoholates. High molecular weight soaps containing metals like magnesium, barium, calcium, tin.	Keep metal surfaces clean and prevent deposit formation of all types.
Dispersants	Metallo-organic compounds such as naphthenates and sulfonates. Organic salts containing metals, like calcium, cobalt and strontium.	Keep potential sludge forming insolubles in suspension to prevent their depositing on metal parts.
Rust preventives	Sulfonates, amines, fatty oils and certain fatty acids, oxidized wax acids, phosphates, halogenated derivatives of certain fatty acids.	Prevent rust of metal parts during shutdown periods, storage or shipment of new or over-hauled equipment.
Metal deactivators	Complex organic nitrogen and sulfur containing compounds such as certain complex amines and sulfides. Some soaps.	Passify, prevent or counteract catalytic effect of metals on oxidation.
Stringiness and tackiness agents	Certain high molecular weight polymers and aluminum soaps of unsaturated fatty acids.	Increase adhesiveness of lubricant on metal surfaces, form protective coating.
Water repellants	Organosilicon and other polymers, certain higher aliphatic amines and hydroxy fatty acids.	Provide water repellant or resistant properties to non-soap thickened greases and other lubricants.
Emulsifiers	Certain soaps of fats and fatty acids, sulfonic acids or napthenic acids.	Emulsify soluble oils with water to give coolant lubricant type fluid.
Dyes	Oil soluble organic compounds with high coloring power.	Provide distinctive or attractive color.
Color stabilizers	Certain hydroquinones, dithiocarbamates, aliphatica amines, dicyclohexylamines.	Stabilize color and prevent formation of undesirable color.
Odor control agents	Certain oil soluble synthetic perfumes, sometimes nitro benzol.	Provide distinctive or pleasant odor or mask undesirable odors.
Antiseptics — (bactericide or disinfectant)	Certain alcohols, aldehydes, phenols, mecuric compounds and chlorine containing compounds.	Control odor, foaming, metal staining, emulsion breaking in emulsion type lubricants.

lubricant properties

HOW IT WORKS
By chemical reaction film is formed on metal contacting surfaces which has lower shear strength than base metal thereby reducing friction and preventing welding and seizure of contacting surfaces when oil film is ruptured.
Wax crystals in oils coated to prevent growth and oil absorption at reduced temperatures.
Improvers are less affected by temperature change than oil. They raise viscosity at 200 F more in proportion than at 100F due to their change in solubilities.
Reduces interfacial tension so small air bubblets can combine to form larger bubbles that separate faster.
Decreases amount of oxygen taken up by the oil thereby reducing formation of acidic bodies. Terminates oil oxidation reactions by formation of inactive soluble compounds or by taking up oxygen. Additive may be oxidized in preference to oil.
Inhibits oxidation so that no acidic bodies are formed or enables a protective film to form on bearings or other metal surfaces. Chemical film formation on metal surfaces decreases catalytic oxidation of the oil.
By chemical reaction or oxidation direction, oil soluble oxidation products are prevented from becoming insoluble and depositing on various engine parts.
Agglomeration and deposition of fuel soot and insoluble oil decomposition products is prevented by breakdown into finely divided state. In colloidal form contaminating particles remain suspended in oil.
Preferential adsorption of polar type surface active materials on metal surface. This film repels attack of water. Neutralizing corrosive acids.
Form inactive protective film by physical or chemical adsorption or absorption. Form catalytically inactive complex with soluble or insoluble metal ions.
Increases viscosity of lubricant and imparts adhesive and tackiness characteristics.
Surface active agents form protective film on grease thickeners or other components of lubricants to reduce their affinity for water.
Surface active chemical agents reduce interfacial tensions so oil can be finally dispersed in water.
The organic compounds with high coloring power (dyes) dissolve to impart color
Certain chemicals can destroy color forming bodies by stopping or changing chemical reaction forming them. Sometimes accomplished by oxidation inhibitors functioning as indicated above.
Small amounts of highly odoriferous substances impart fragrant or pleasant odor when mixed with lubricants.
Used in soluble oils to reduce or prevent growth of bacteria causing deleterious effects in emulsion lubricants.

Source: Texaco's magazine, LUBRICATION, Beacon, N. Y.

are particularly useful in pumps handling hot liquids and in corrosive atmosphere. Recent tests on lightly loaded small ball bearings show that silicones have much lower torque characteristics than the petroleums or the polyglycol synthetics (coastdown time of silicone-lubricated bearings were longer). Other research with silicones indicates that the incorporation of halogen atoms into the molecule increases the steel-to-steel load-carrying capacity.

Silicate esters

These are closely related to the silicones—but, unlike the silicones, additives may be used. They can also be combined with other lubricants. Their outstanding qualities are their excellent viscosity-temperature characteristics and their low volatility. With proper oxidation inhibiters they operate for periods of 50 to 100 hours at temperatures around 500 F. However, above 400 F abrasive deposits may form.

Similar to the silicones, they have little effect on most plastics and synthetic rubbers. They are appreciably cheaper than the silicones. But they tend to hydrolize readily. Any water which comes into intimate contact with many of these silicate esters causes them to break down, forming a gel or abrasive silica deposit. This tendency can be inhibited only partially by additives.

Main applications are in heat-transfer fluids in both low- and high-temperature hydraulic fluids, and as a constituent of low-volatility, low-viscosity grease bases.

Polyglycol-ether compounds

These are available in several types, the principal ones being a water-soluble series and an oil-soluble (or at least water-insoluble) series.

Key advantages of these lubricants: They can be substituted in machines for petroleum lubricants with no need for design or material modifications. They are also the cheapest of the synthetics. They have excellent viscosity-temperature characteristics; low volatility, comparable with that of the silicones; and good lubricity. They are compatible with many synthetic lubricants, and additives may be employed to further improve their properties.

Main limitations of this group: They are practically incompatible with petroleum oils, and they attack paint and other nonmetallic materials—but they have little effect on rubber. They are employed in engine oils where they produce viscosity properties bracketing several SAE numbers. The water-soluble series are finding increasing use in hydraulic fluids for aircraft controls

and automotive brakes. Other uses include, forming and drawing lubricants, low-temperature grease bases and vacuum-pump lubricants.

Fluorinated and chlorinated fluids

The hydrogen atom in these compounds has been replaced by either fluorine or chlorine. The compounds are relatively inert.

Of the two, the older and more widely recognized are the chlorinated hydrocarbons which have very high load-carrying capacity and are often used as extreme-pressure additives. Hydrolytic stability is good; thermal stability and fire resistance excellent. Main drawbacks are poor viscosity, temperature characteristics and high price. Key applications are nonflammable extreme-oxidation-resistant lubricants, and as a heat-transfer fluid.

Polyphenyl ethers

These push up the temperature limit of lubricants a full 200 F over the silicones. One type was recently reported as doing a good job of lubricating rolling-element bearings at 800 F in a recirculating system for over 20 hrs. They are also excellent under severe oxidation and radiation.

Pour points of the ethers are considerably higher than those of the MIL-spec fluids, but this is acceptable in some systems. At normal temperatures, their lubricating properties equal those of petroleum oils.

SUPER-REFINED PETRO OILS

Although the new synthetics developed over the past decade are beginning to dominate the field of specialized lubricants some researchers are taking a new look at highly refined or "super-refined" petroleum oils. This approach is now being investigated at Pennsylvania State College under an Air Force contract and has already produced an experimental fluid for use from −40 to 550 F.

Super-refined mineral oils are conventionally refined oils that have been treated by severe hydrogenation, acid treatment or absorption to remove or reduce polar impurities, unsaturates, and unstable hydrocarbon structures. This improves oxidation and thermal stability and reduces corrosivity and viscosity change. Drs. Merrell R. Fenske and E. Erwin Klaus, heading the research at Penn State, predict new base stocks from petroleum oils to which additives can be added which will produce lubricants having all of the properties of the best synthetics—but at a much lower price.

ADDITIVES

This is the area where most of the research on lubricants is concentrated. New additives are continually being developed to improve the properties of the oils, synthetics, greases. These are special substances (see table on page 76) added to lubricant in amounts up to about 10% to:

- Improve the lubricant to perform under more severe conditions.
- Impart new properties to the lubricant.
- Replace desirable compounds removed from the crude oil during refining or other processing.

An all-purpose automotive petroleum oil, for example, may contain as many as eight additives to handle the lubrication of cylinders, bearings, valves, and timing gear: extreme-pressure and oiliness additives, pour-point depressants, viscosity-index improvers, detergents, foam and corrosion inhibiters and anti-oxidants.

Current status of EP additives

Organic phosphorous compounds are mild EP agents employed exten-

Comparison of

MULTIPURPOSE GREASES

SOAP BASE	BARIUM	LITHIUM	CALCIUM-COMPLEX
KEY PROPERTIES	• Low-cost multipurpose grease. • Good resistance to water.	• Multipurpose grease. • High and low temperature capabilities. • Excellent resistance to water. • Easily pumped. • High mechanical stability.	• Multipurpose grease. • Good high and low temperature characteristics. • High mechanical stability. • Very high melting point.
TEXTURE	Smooth to fibrous	Smooth to buttery	Smooth to buttery
Max continuous usable temperature (avg)	275 F	275 F	400 F
Water resistance	Good	Good	Excellent
RESISTANCE to breakdown and softening by working	Poor to fair	Good to excellent	Excellent
BEHAVIOR after 250 F and cooled when worked	No change	No change	No change
PRINCIPAL USES	Multi-purpose; all bearings; for general automotive lubrication.	Aircraft; multipurpose; for superior performance under widely varying conditions.	High temperature applications.
REMARKS	Because of their high soap content, may cause trouble in dispensing systems, in very high speed bearings, and in low temperature applications.	Have best available low temperature characteristics, and are good for high temperature. Much depends on formulation. Some have highest known mechanical stability.	Vastly different from the calcium soap greases. Melting point over 600 F. Usually limited by its property of oil base.

eight lubricating greases

SPECIALIZED GREASES

CALCIUM	SODIUM	MIXED BASE	ALUMINUM	LEAD SOAP
• Good resistance to water. • Easily pumped.	• Good high-temperature properties. • Excellent adhesive and cohesive characteristics.	• Combines characteristics of calcium and sodium soaps.	• Fair resistance to water. • Special tacky or adhesive qualities.	• EP or heavy load-carrying characteristics. • Good resistance to water.
Smooth, buttery	Fibrous or buttery	Varies	Smooth to stringy, never fibrous.	Smooth
160 F	250 F	Varies	180 F	175 F
Good	Fair	Varies	Good	Good
Fair to good	Fair to excellent	Varies	Poor to fair	Fair
Separates	No change	Varies	Liquifies	–
Cup; pressure gun; general purpose industrial use.	Anti-friction; plain bearings; flat surfaces; for moderately high temperature lubrication.	Life-lubricated bearings; special lubrication for varying unusual demands.	Chassis fittings; oscillating bearings; where extreme tackiness or insolubility is needed.	Heavy industrial machinery; conditions of shock or overloading; partially enclosed gearing.
Above 160 F, greases lose water, necessary to their stability, and separate into original oil and hard soap. Below 160 F mechanized stability is good.	Good working performance at moderately high temperatures.	Vary widely with ingredient mixtures. Includes the very stable, oxidation inhibited greases used in "life-time" lubricated bearings.	Very tacky, never fibrous. If heated above melting point, they may "set up" and then cool in that condition.	Heavy and medium grades valuable as gear shield lubricants. Soft grade for journals.

Source: G. H. Link, Shell Oil Co., N. Y. and J. G. O'Neill, Jr., Sinclair Refining Co.

sively to improve antiwear resistance. In some forms they improve the oxidation stability of oils—particularly at elevated temperatures. They react only mildly with metal, and they are not usually corrosive.

Chlorine additives give lower wear and friction than those where chlorine is attached to an aromatic nucleus. Chlorine in some gear lubricants and in other applications has proved very effective.

Sulphur additives combine with metal to form surface films that improve load-carrying properties. But they can cause excessive staining or corrosion of nonferrous metals such as copper alloys.

Lead-sulphur additives are effective in lubricants for heavy machinery. Current improved formulations use lead in a form such as lead naphthenate, to which an effective sulphur compound is added.

Two popular misconceptions are: (1) The greater the content of the additive, the better the results. Actually, the contrary may be true because some EP agents adversely affect other lubricant properties such as demulsibility, stability, surface tension, tendency to form or corrode the surfaces. (2) The lubricant viscosity becomes insignificant in the presence of EP agents. Not true, because heavier viscosity of the fluid may affect not only the occurrence of boundary film conditions, but also the formation of full fluid films. Recent gear tests show that

Viscosity recommendations for electric motors

(Viscosity, SSU at 100 F)

APPLICATION METHOD	SPEEDS UNDER 1500 RPM	SPEEDS 1500 RPM AND OVER
Pressure lubrication	150-500	100-200
Oil-level system	150-500	100-200
Wick Feed	300-500	150-300
Spray feed (slinger)	200-500	100-200
Oil ring	300-500	150-300
Waste packed	300-500	150-300
GREASE LUBRICATION AT ANY SPEED		
Pressure gun	NLGI No. 2 Grease	
Packed	NLGI No. 2 Grease	
Grease cups	NLGI No. 2 Grease	

Source: B. M. Dunham, Sun Oil Co., Philadelphia.

Viscosity recommendations for chain drives

TYPE OF SERVICE	OPERATING TEMP, F	TYPE OF CHAIN	VISCOSITY SSU AT 100 F	SAE NO.
Slow speed	Below 40	Silent	300-350	20
		Roller or block	500-600	30
	40—100	Silent	500-800	30-40
		Roller or block	700-1200	30-40
	Above 100	Silent	700-1200	30-40
		Roller or block	1000-2500	40-50
Medium speed	Below 40	Silent	200-325	20
		Roller or block	300-350	20
	40—100	Silent	300-550	20
		Roller or block	500-600	30
	Above 100	Silent	500-600	30
		Roller or block	700-1200	30-40
High speed	Below 40	Silent	200-325	20
		Roller or block	200-325	20
	40—100	Silent	300-350	20
		Roller or block	300-550	20
	Above 100	Silent	300-550	20
		Roller or block	500-800	30-40

Source: Allen F. Brewer.

between two EP lubricants, identical except for viscosity, it is the higher viscosity product that carries more load.

GREASES

For many years, the ASTM defined a grease as a "combination of a petroleum product, and a soap or mixture of soaps". This definition, however, did not cover the newer greases made from synthetic lubricants, and those made without soap by utilizing bentones or silica gels as thickening agents. The new ASTM definition is more general—but more obscure: "a solid to semi-fluid product of dispersion of a thickening agent in a liquid lubricant."

Petroleum greases

Lubricating oil constitutes the greatest proportion, 75 to 95% of either petroleum (Gulf-Coast, Mid Continental or Pennsylvania base), or synthetic (liquid silicones, esters, polyglycols, etc).

Almost all the petroleum greases contain a soap as a thickening or gelling agent. A comparison of eight soap-base greases is given on page 78. Extreme-pressure or other additives, as used in liquid lubricants, are frequently incorporated. Solid fillers and additives, such as molybdenum disulfide, graphite, talc mica, zinc, lead soapstone, are sometimes added to the grease where severe mechanical conditions are anticipated. The use of molybdenum disulfide as a grease additive has grown rapidly in the past few years because of its excellent performance under very heavy load and under high temperatures. It is very stable and unaffected by water, alkalies and most acids.

Synthetic greases

Synthetics are rapidly moving into the grease field. Many are a combination of synthetic lubricant and a standard soap. Others such as silicones are completely synthetic. Synthetics are well suited for use at temperature extremes—many are divided according to temperature of use. One silicone grease, for example, is recommended for ball bearings anywhere from −100 to 300 F, a second type for −20 to 450 F, and upward. The silicone greases are also highly resistant to water and oxidation, and are well suited for use in presence of chemical fumes.

Improved grease performance

When two greases of the same chemical type and with approximately the same consistency—but differing in thickener content—were tested, the grease with more thickener gave significantly longer ball-bearing life. This held true for 13 products, including lithium and sodium soap-thickened silicone greases. It also held true from 100 C to 175 C, and for speeds from 3600 to 7000 rpm.

These remarkable tests were conducted by A A Schwartz of General Electric, Schenectady. Bearings employing the grease with higher thickener content had life spans generally from two to four times longer. He found it surprising that no one has tried a similar study and attributed his results to actual tests with ball bearings rather than using the typical lubricant bench tests.

HIGH-TEMP LUBRICATION

Many specialized materials are being considered for lubrication at high temperatures. These can be divided into the three states of matter: gases, liquids and solids. A look at the status today and potential capabilities is given in the chart on page 75:

Gases

Gas-lubricated bearings have been highly successful in very high speed, low torque mechanisms. The properties of the gas usually is not important as long as consideration is given

to such possible side effects as corrosion of the bearing materials. However, certain gases can provide lubrication even when seizure or boundary conditions occur. Sulfur vapor, which shows promise up to about 1800 F, meets these objectives.

Inert gases, such as nitrogen, are being used as atmospheres above more conventional lubricants to minimize lubricant deterioration and material corrosion at elevated temperatures.

Halogenated ethanes are effective lubricants for cermets sliding on Co-base alloys at temperatures up to 1400 F. They are stable at 1000 F but the extremely high frictional heat developed causes these gases to react with the sliding surfaces. Corrosive wear under these conditions is a possibility. The type of halogenated ethane employed must be compatible with the bearing material. For example, Co-base alloys are more effectively lubricated by chlorine-containing gases at 1000 F than by bromine-containing gases, whereas Ni-base alloys react more favorably to bromine-containing gases up to 1400 F.

Liquids

Ordinary mineral-oil systems are limited to about 350 F maximum in air because of vaporization and oxidation. Maximum allowable temperature for usual mineral-oil systems under an inert gas can reach about 500 F. Military specs for fluid lubricants suitable for bearings and gears of jet engines include:

MIL-L-7808 —under 400 F
MIL-L-9236 —at 400 F
MIL-L-27052—at 500 F
MLO-7415 —at 600-700 F

Fluids based on trimethyl propane esters meet the requirements of MIL-L-9236; however, polyglycol ethers, alkyl diphenyl ethers, silicate esters and silicones appear promising. MIL-L-9236 fluids have lower load-carrying capacities than MIL-L-7808 fluids. No fluid is yet qualified for MIL-L-27502. Severe oxidation at temperatures above 400 F appears to be the principal disadvantage of most current fluids.

The special mineral oils qualifying under MLO-7415 exhibit a substantial increase in oxygen tolerance over MIL-L-7808 and MIL-L-9236 jet-engine lubricants in the 600-700 F range. Special additives may soon overcome this problem.

MIL-H-8446A fluids are siloxanes and are qualified for hydraulic use to 400 F. There is a need, however, for hydraulic fluids useful above 400 F. The special mineral oils, under MLO-7415, and phenoxy phenyl ethers look promising in this range.

Certain metals can also be employed as liquid lubricants at high temperatures. Receiving the most attention is the NaK 77 eutectic—although it has poor lubricity characteristics and reacts rather violently with water. Among the other disadvantages are disposal problems, corrosiveness, and poor lubricity characteristics and rials. Gallium is another contender as a liquid-metal lubricant.

Some military specs for high temperature greases are:

MIL-L-3545 —to 300 F
MIL-G-25760 (USAF)—to 350 F
MIL-G-25013A —to 450 F

Silicones as grease vehicles and synthetic thickeners offer the most promise of meeting the specs. As with fluid lubricants, increasing temperatures drastically hinder the use of greases. As an example, the performance life of a MIL-L-3278A grease decreases from about 500 hours at 300 F to about 100 hours at 350 F. At 600 F, it has only about 1/10 of the life which it had at 400 F when lubricating a ball bearings operating at 20,000 rpm.

Solids

The Air Force recently established a goal of 1000 F and 80,000 psi for dry-film lubrication at 400 fpm. MIL-L-25504 specification covers dry-film lubricants and requires 5-hr life at 500 F.

The common solid lubricants are graphite and MoS_2. Graphite in air, and MoS_2 in nitrogen are satisfactory to temperatures of about 1000 F. However, graphite produces increasing friction above about 700 F. In air, MoS_2 performs satisfactorily only to about 850 F. The newer solid materials considered as lubricants include PbI_2, PbO, WS_2, AgI, Ag_2SO_4, BN, and various mixtures of these. These materials are often bonded to surfaces with resins or inorganic materials such as $NaPO_3$, $Na_2B_4O_4$ and Na_2SiO_3. The inorganic binders will, in general, withstand higher temperatures than the resin binders.

Bonded PbO has a coefficient of friction which decreases with increasing sliding velocity and with increasing temperature. It has been employed successfully to 1250 F, but it oxidizes to Pb_3O_4 at about 800 F which is much more abrasive than PbO. SiO_2 mixed in this film minimizes this oxidation. Phenolic bonded graphite is more wear

Viscosity recommendations for machine tools

(Viscosity, SSU at 100 F)

MACHINE PART	ENGINE LATHE	TURRET LATHE	AUTOMATIC SCREW MACHINE	MILLING MACHINE	GRINDING MACHINE	DRILLING, TAPPING OR THREADING MACHINE
Main drive gearbox	—	—	200-300	200-300	—	150-300
Headstock	300-500	150-300	200-300	200-300	150-200	150-300
Speed-change gearbox	300-500	150-300	200-300	—	—	150-300 or GS
Feed gearbox	300-500	150-300	—	200-300	150-200	150-300 or GS
Traverse gearbox	—	140 EP	—	140 EP	140 EP	140 EP
Worm gears	—	—	140 EP	140 EP	90 or 140 EP	140 EP
Spindle	300	200-300	150-300	100-300 or G	30-300 or G	50-300 or G
Apron, carriage, ways	W	W	W	W	W	W
Lead or feed screw	W	W	—	W	W or 300	W

Source: B. M. Dunham, Sun Oil Co., Philadelphia.

CODE: *90 EP*–SAE 90 mild non-corrosive extreme pressure oil; *140 EP*–SAE 140 mild non-corrosive extreme pressure oil; *W*–SAE 80 type way lubricant having a viscosity range of 300 to 350 SSU at 100 F, and having oiliness and EP characteristics; *GS*–semi-fluid grease for gearboxes on drilling machines; *G*–general-purpose grease.

Lubricants for instrument bearings

MIL-L-6085A: Covers lubricating oil for aircraft instruments. For high- and low-temperature applications where oxidation and corrosion resistance, and low evaporation are desirable. Oils meeting this specification consist substantially of synthetic-base oil—usually diesters containing additives.

SOME SOURCES	NAME	TEMPERATURE RANGE, F
Shell Oil Company	Aeroshell Fluid #12	–70 to 365
Lehigh Chemical Company	Anderol L-401-D	–75 to 460
E F Houghton	Cosmolubric No. 270	–65 to 250
Eclipse Pioneer Division	Eclipse Pioneer #10	–65 to 300
Esso Standard Oil Company	Univis P-38	–65 to 300
F E Anderson Oil Company	Winsor Lube L-245X	–65 to 400

MIL-L-644A: Covers a general-purpose low-temperature corrosion-preventive oil for moving parts of small arms and small aircraft mechanisms. Consists of a petroleum base containing additives.

SOME SOURCES	NAME	TEMPERATURE RANGE, F
Lehigh Chemical Company	Anderol L-444	–
E F Houghton	Cosmoline No. 1044	–65 to 250
Gulf Oil Company	Gulfite Oil 6	–90 to 210
Shell Oil Company	Shell Lubricating Oil	–
Texas Oil Company	Texaco 1692	–65 to 200
F E Anderson Oil Company	Winsor Rust Prev. L-1384	–

MIL-L-7870A: Covers a general-purpose low-temperature lubricating oil, usually of petroleum base. This spec is especially concerned with low evaporation, rust prevention, anti-gelling or separation, and low-temperature stability.

SOME SOURCES	NAME	TEMPERATURE RANGE, F
Shell Oil Company	Aeroshell Fluid #3	–
E F Houghton	Cosmolubric No. 263	–65 to 200
Esso Standard Oil Company	Aviation Instrument Oil	–70 to 180
Gulf Oil Company	Gulfite Oil 6	–90 to 210
F E Anderson Oil Company	Winsor Lube L-1018	–

MIL-L-17353A (NOrd): A light synthetic lubrication and preservative oil primarily for instruments operating in critical applications at low temperatures. Composition is usually diesters with additives.

SOME SOURCES	NAME	TEMPERATURE RANGE, F
Lehigh Chemical Company	Synthetic Oil L-451	–90 to 300
F E Anderson Oil Company	Winsor Lube LS-252	–75 to 350

MIL-G-15793 (BuOrd): A grease intended for lightly loaded fire-control instruments such as synchros, gyros, gears, bearings, and small precision instruments and devices. Specification covers an operating range for –65 F to 250 F with special properties with respect to evaporation, rust prevention, and oxidation stability.

MIL-G-3278: Grease for rolling-element bearings, and sliding and rolling surfaces. Its liquid is usually a diester. This grease is particularly suitable for both low and high temperatures, from –65 F to 250 or 350 F.

SOME SOURCES	NAME	TEMPERATURE RANGE, F
Shell Oil Company	Aeroshell Grease No. 11	–65 to 250
Standard Oil Company of New Jersey	Beacon 325	–65 to 300
	Uni Temp Grease Texaco 1959	–67 to 350

Source: R. F. Irwin, Miniature Precision Bearings Inc., Keene, N. H.

resistant, but less temperature resistant, than ceramic bonded PbO. Boric oxide is good binder for MoS_2 films up to 700 F. Phosphate surface treatments improve life performance of these films at temperatures to 400 F.

Methods of lubrication

For the milder temperature ranges and with temperature resistant fluids, the conventional full-fluid or packed-bearing systems are satisfactory. For operation in the somewhat higher temperature ranges, a lubricant mist or "once-through" technique or both, is useful. For the even higher temperature ranges, the solid-film systems or gas are of importance. In many of these various systems the useful temperature range for the lubricant can be increased by providing an inert, protective, or controlled atmosphere for the lubricant.

For **Reprint** of above article, just check 630 on one of the Reader Service cards found in this issue.

Editor's note: Our thanks are due to L B Sargent Jr, Chief, Lubricants Div, Alcoa Research Labs, Aluminum Company of America, New Kensington, Penna, for the information on high-temperature lubricants.

Solid-film lubricants have been discussed only briefly in this report. For recent evaluations see:

How Good Are Solid-film Lubricants for Extreme Environments?, June 12 '61, p 70. An up-to-date review of research aimed at finding a lubricant for 1000 to 2000 F and for high-vacuum service.

For high Pressures, Low Viscosities—Bonded Coatings Lubricate Metal Parts, Sep 5 '60, p 48. Adding a solid lubricant like graphite or molybdenum disulfide to a resinous or inorganic binder gives a slippery coating that can be cured in place. Article gives latest performance data on these coatings, including newer high-temperature types.

Press-fit Test Pick Solid Lubricants for Extreme Pressures, June 22 '59, p 64. Lists friction coefficients of a large number of solids as possible extreme-pressure lubricants or anti-seize compounds.

For more information on lubrication of bearings and gears see:

New Developments in Lubrication, May 15 '61, p 98. Gives a comprehensive report of ASLE meeting with references to a wealth of new equations, design charts.

Now—Mist Lubrication for Air Bearings, Aug 29 '60, p 54. Shows how boundary film may be the answer when air pressure alone is insufficient to prevent metal-to-metal contact.

When purchasing components, is Reliability guaranteed?

The tests and the selection of a vendor are two key factors in obtaining reliability. Here's how to provide procedures and controls for both.

H E VANDENBERG, engineering specifications, Convair (San Diego) General Dynamics Corp

The specification or specification control drawing, primarily a word picture of the item, must be specific in its requirements, concise in its language and clear in its intent, if the required reliability is to be achieved in a product. The engineer must, therefore, keep in mind the "state of the art" when preparing them. Component manufacturers and specialty departments are constantly improving their products, and the specification or control drawing must reflect these advances.

However, it is unwise to exceed the state of the art to such a degree that producibility of the item is impractical. This results in a great deal of vendor–contractor consultation to resolve the problem, and makes it necessary either to grant deviations or to make revisions. Also, frequent relaxation of requirements may tend to identify the design originator as an easy mark for deviation requests, which in turn may have an adverse effect on vendor–contractor relationships.

The engineer preparing design-control documents should check the realism of his design, construction, performance and test requirements through coordination with other cognizant groups and departments: other applicable design groups, reliability and producibility groups, the quality control department. Assurance of reliability can best be attained by including specific production and qualification-test requirements. Procedures and equipment and the results of testing should be subject to the approval of the prime contractor's engineering department. Production tests specified should evidence the manufacturer's continued maintenance of best production and quality-control methods. Qualification tests should demonstrate the item's ability to meet all design requirements. Qualification test conditions should at least equal the worst extremes that the item may possibly encounter during service. Test setup, for valid results, should simulate, as nearly as practical, normal installation of the item.

Selection of a vendor plays a major part in assuring reliability. Many factors must be considered, including:

1. Integrity.
2. Condition of manufacturing facility and equipment.
3. Labor-management relations and capabilities of engineering and production personnel.
4. Quality-control program employed.
5. Comparative analysis of vendor's proposed design and engineering data.
6. Ability to supply items in quantities sufficient to support production schedule.
7. Attitude relative to submittal of support data required by the prime contractor.
8. Geographical location.

The competitive-bid method of vendor selection currently employed by most component or end-item manufacturers offers an excellent opportunity to do something constructive about reliability. This system is not foolproof, however, and poor control procedures can cost all that the manufacturer had hoped to gain. For example, bids and supporting engineering data from each of the vendors competing for a contract will probably be submitted at different times. Thus, the engineer may be making his analysis of one vendor's data without knowledge of what competing vendors have to offer. Individual analysis of vendor proposals does not afford the opportunity for engineering to recommend procurement of the superior unit, and purchasing may well procure inferior units on the basis of unit price alone. The result will be reduced reliability.

To avoid this, purchasing should hold vendor bids and supporting data until all have been received, then list all data collectively on one multicopy data-transmittal form accompanied by the proposals themselves. Engineering can thus evaluate each of the proposed items on a comparative-merit basis. In turn, each control group studies the proposals for its particular functions, then retains a copy of the transmittal sheet.

From the reports, purchasing selects the most suitable vendor. Engineering and applicable data-control groups should be notified as soon as possible of the final selection, to facilitate proper follow-up.

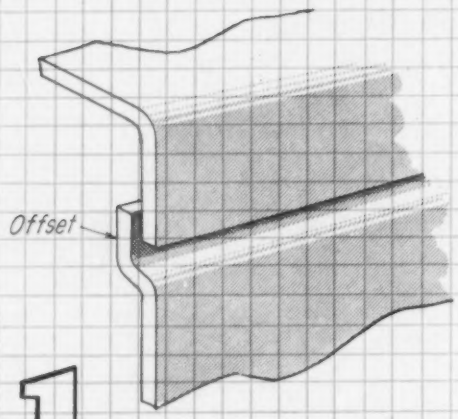
Information on the transmittal form should include, but not necessarily be limited to:

1. Procuring contractor's end item part number.
2. Vendor's name and part number.
3. Identification of all data submitted by each vendor.
4. Unit-price information (each vendor).
5. Identification of procuring contractor's applicable data requirement.
6. Date of submittal to engineering.

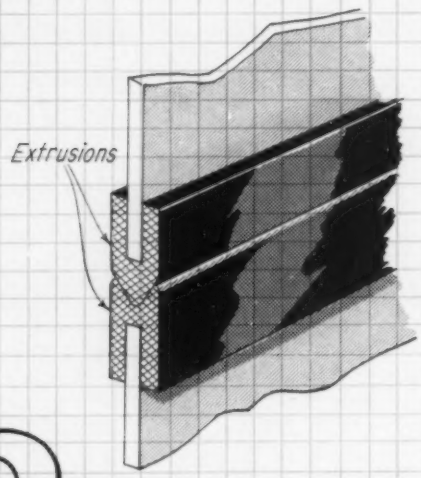
Optimum reliability will not just happen, but must be the product of tempered futuristic engineering and well-coordinated purchasing and quality-control administration.

8 Instrument seals

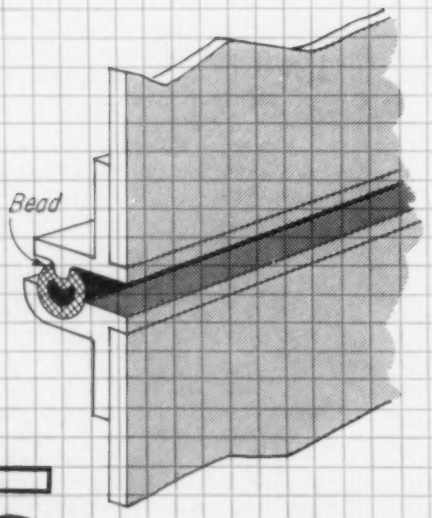
Besides keeping water and dirt out of the instrument case, they must also strengthen the rim.



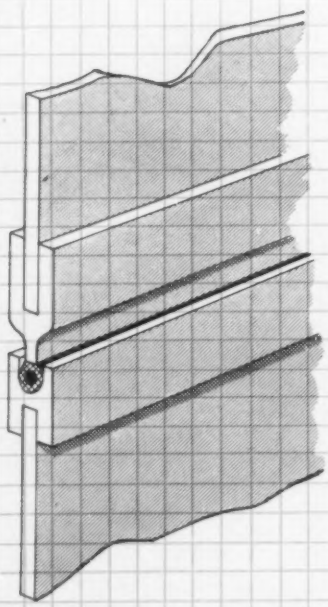
1 **OFFSET** is economical, but little else. Although it will keep out dust and rain, the weak rim warps easily.



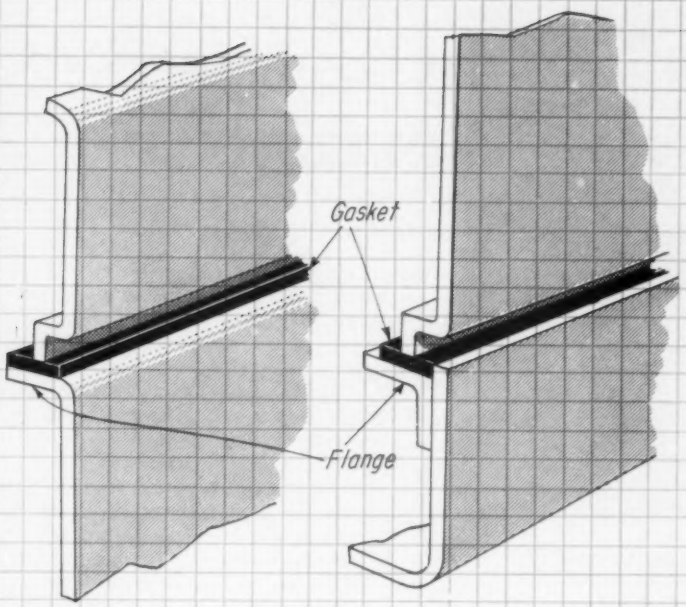
2 **EXTRUSIONS** cover raw edges and improve appearance. They are usually aluminum, rubber or plastic.



5 **BEAD** seals better, reduces closing force. For maximum rigidity extrusions should be eight times as wide as they are thick.

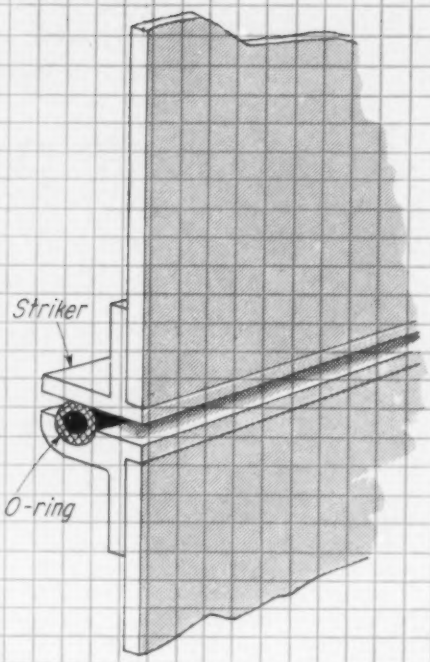


6 **SPACE-SAVER** allows fuller use of inside of box, yet has neat appearance and tight-sealing O-ring. But it leaves rim weak.



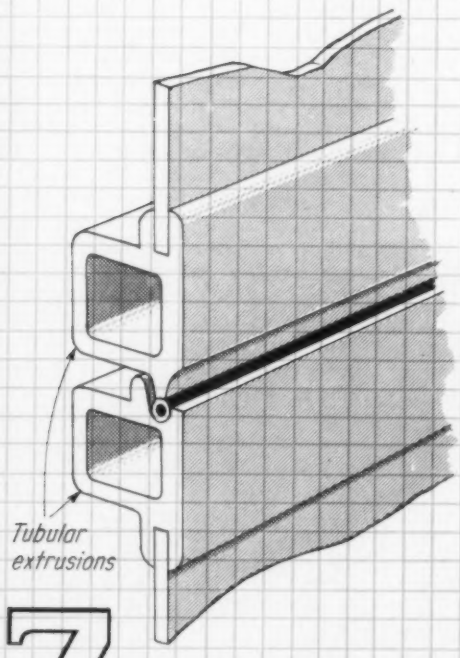
3

FLANGE, especially a separate extruded one, strengthens the rim. When extended, it is a mount for equipment inside. Gasket slightly improves seal.



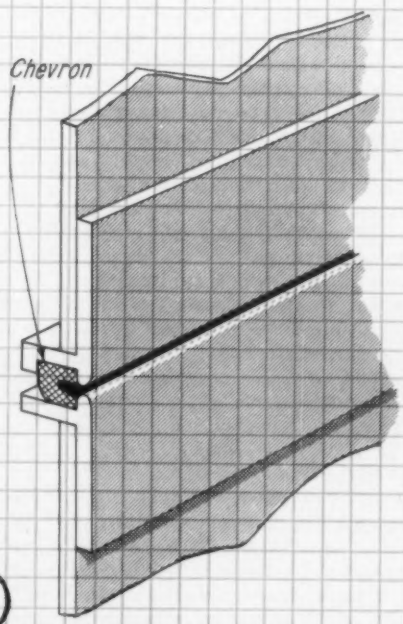
4

O-RING gives good seal when combined with heavy-duty latches which press flat striker down hard on wide contact area. Extrusions top and bottom reinforce rim.



7

TUBULAR EXTRUSIONS beef up rims of large shipping containers. Pieces for making right angle bend at corners are die-cast.



8

CHEVRON requires only light pressure to seal. Even if rubber sets permanently, it still keeps out water with three to five foot head.

For straight-line thrust try a standard

Linear power actuator

The correct off-the-shelf actuator will "pick itself" if you let it. Questionnaire and performance checkoff list do the trick.

G A FRANCIS, chief engineer, new devices section, Skinner Precision Industries Inc, New Britain, Conn

FOR BUILT-IN push or pull (operating rods on packaging machines, power or control actuators on earthmovers, automatic clamps and positioners on machine tools) specify an off-the-shelf actuator package if possible. Chances are there is one available and it will save design time and money.

The choice is generally limited to solenoids, cylinders, and motor-driven screws. Less well known is the linear induction motor, which physically resembles a solenoid but has completely different performance characteristics. Axial movement of its armature is by induction instead of magnetic attraction and force is constant throughout any length stroke. (See facing page for detailed description.)

Each of the four linear actuators—solenoid, linear induction motor, cylinder, screw—is suited to certain applications but not to others, and a comparison of your requirements with the performance table will quickly narrow the choice.

Not all applications can be satisfied with just the four actuator types compared in the table, of course. Special-purpose actuators may be needed, and there is a large variety of these.

One company makes an interesting variation of a cylinder actuator called a Thrustor (trademark) that is a packaged electrohydraulic unit. It is a special cylinder and piston with an integral motor-driven centrifugal pump. When the motor is energized, the piston of the unit moves upward. When motor is stopped, the piston is free to return by gravity or mechanical force. Force level can be several thousand pounds and stroke up to 16 in.

Job requirements
Output force, lb
constant
adjustable
repeatable
reversible
Stroke, in.
hold end position
intermediate
Speed, in./sec
fast response
uniform response
adjustable speed
Size important
Power source
Cost important

Fluid compressibility is the basis of another special actuator: it is essentially a liquid spring (PE—Aug 17 '59). The rod is first depressed, compressing a volume of fluid (total volume of fluid is large compared with volume displaced by the rod, therefore percent compression is small). When load is released, the rod extends. The principle is useful where rapid rod extension is desired, and where the energy must be stored in advance.

The linear induction motor (one is pictured on next page) has interesting variations. Some manufacturers use a flat strip instead of a rod for the linear armature, but the principles are the same. In one design, the strip is held fixed, and the motor moves. In another version (for direct-current application) commutators are built into the device and there is no synchronous speed; it resembles a dc motor in electrical performance. Applications for custom-built linear motors include continuous conveyor belts (the moving armature is a flexible strip of metal) and semi-rotary actuators (the armature is pivoted and moves in a large-radius arc instead of in a straight line).

Rack-and-pinion actuators are available as a package from at least one manufacturer. A motor drives the pinion; the rack output force can be several hundred pounds, and stroke several feet. Cable actuators are also available. They are simply motor-driven pulleys that draw in or pay out cable as needed. Any amount of force or travel can be provided if size and cost are not limited.

Thermal actuators (PE—July 11 '60, p 74) are energized electrically to expand a thermally sensitive material, and can exert high forces through limited strokes. Bellows-type actuators, powered by gas or liquid, are also available, but are usually custom designed.

There are as many ways to get linear actuation as there are engineers to dream them up, but this article will be

limited to these four common packaged units: solenoids, linear motors, cylinders and motor-screws.

4 steps to the right actuator

- List job requirements by filling in the blank questionnaire shown on the previous page.
- Eliminate obviously unsuitable actuator packages (performance characteristics are listed on next page).
- Narrow final choice to best one or two as determined by the qualifications (see text).
- Pick actual component by consulting several manufacturers.

The job sets the requirements so the questionnaire should be filled in carefully. Three of the performance categories are obvious: force, stroke, speed. Equally important sometimes are size, available sources of power, and installed cost. If space is limited, a hydraulic cylinder may be the only answer. If electricity is the only power source, a solenoid or linear induction motor may prove cheaper than installing a hydraulic system with reservoir, pump, motor, and accessories.

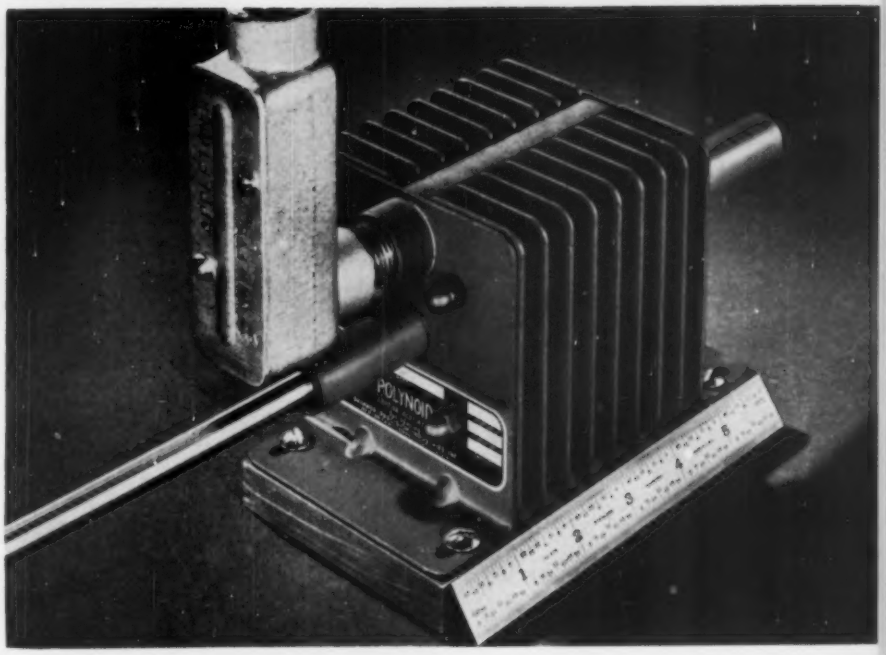
Don't overlook special requirements of temperature, reliability, vibration, contaminants, voltage or pressure variations, efficiency, noise (mechanical or electrical), maintenance, effect on adjacent equipment and safety (explosionproof systems may be required).

Temperature affects the operation of all actuators. To insure repeatability, temperature should be maintained constant within rated limits. If temperatures are very high, special designs and materials will be needed. (Normal ambients and operating conditions will be assumed here because most standard components are so rated.)

The performance table augments the job-requirement questionnaire. With it you can quickly select likely actuator candidates and eliminate the unsuitable ones. Headings are necessarily brief; here are the limitations in the table.

Output force — Ranges are based on catalog data from many manufacturers. All values are conservative, however, and much higher ratings are available. For instance, ac solenoids have been built to exert 100-lb force and some dc units can reach 10,000 lb. Linear induction motors have been operated well over 100 lb, and a 10-in. diameter 500-psi hydraulic cylinder delivers approximately 40,000 lb. force. However, for ordinary "hardware" components available from many suppliers, the performance table is representative.

text continued, next page



LINEAR INDUCTION MOTOR

Operation of a linear induction motor (see *PE—June* 12 '61, *p* 89) is analogous to that of an ac squirrel-cage induction motor. The ac supply generates a moving magnetic field (axial for the linear actuator, rotary for the squirrel-cage motor). This moving field induces current in the copper sleeve covering the actuator rod (analogous to the rotor windings). Interaction between induced current and traveling field causes the actuator rod to follow the field.

Wiring of the coils in proper sequence causes peak voltage to occur in the adjacent magnetic-iron pole plates in sequence, which creates the traveling magnetic field. The only moving part is the actuator rod.

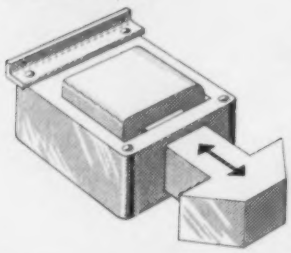
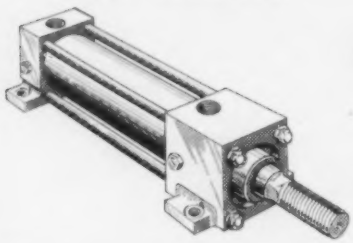
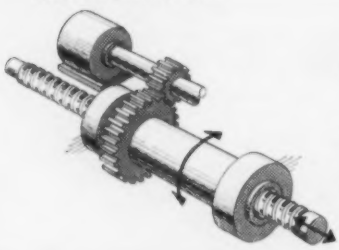
Actuator is usually "holding" or operating at high slip—as when a squirrel-cage motor operates with locked rotor or at high slip. Synchronous speed of this actuator is 105 in./sec for single-phase, 160 in./sec for 3-phase.

A shift in phase sequence of a polyphase unit or a change in capacitive shifting of a single-phase unit will reverse force and give reciprocating motion (it can drive a pump or compressor).

Photo is of a polyphase linear induction motor with individual field coils separated by magnetic iron spacers. Magnetic flux for each coil is via adjacent spacer, inward across airgap (including copper sleeve), through actuator rod (iron core), outward to next spacer, across outer ring and back to first spacer.

Inherent characteristics of this actuator in standard sizes are: Unlimited stroke lengths (only limitations are mechanical—related to bearings and load alignment). Force is uniform at any position in the stroke. Power requirements are uniform throughout stroke. Response rapidly follows energization. Output force is directly proportional to input power (varied by voltage control). Force is 2 lb continuous, 30 lb intermittent or with cooling.

Performance of linear

key for "relative" performance 1—most suitable 2 to 6—less suitable		OUTPUT FORCE				
		RANGE, LB	VARIATION DURING STROKE	RELATIVE REPEAT-ABILITY	RELATIVE EASE OF ADJUSTMENT	REVERSIBILITY
ELECTRICAL						
	SOLENOID	0-30	VARIES	2	3	NOT SIMPLE
	LINEAR INDUCTION MOTOR	0-30	CONSTANT IF VOLTAGE IS CONSTANT	1	2	READILY REVERSIBLE IN STANDARD ACTUATORS
FLUID CYLINDER						
	PNEUMATIC	0-1400	CONSTANT IF PRESSURE IS CONSTANT	4	1	READILY REVERSIBLE IN STANDARD ACTUATORS
	HYDRAULIC	0-15,000	CONSTANT IF PRESSURE IS CONSTANT	4	1	READILY REVERSIBLE IN STANDARD ACTUATORS
MECHANICAL						
	BALL SCREW	0-1200	CONSTANT IF VOLTAGE IS CONSTANT	3	4	READILY REVERSIBLE IN STANDARD ACTUATORS
	PLAIN SCREW	0-1400	CONSTANT IF VOLTAGE IS CONSTANT	3	4	READILY REVERSIBLE IN STANDARD ACTUATORS

Force variations during stroke length are greatest in a solenoid. Force increases rapidly as the plunger approaches its seat and the air gap becomes smaller. The other devices have relatively constant force during the stroke if voltage or pressure is held constant and speed does not exceed rated values. At the theoretical maximum (synchronous) speed of linear and rotary motors, output forces drop to zero. In cylinders, forces drop to zero when flow rate reaches the capacity of the fluid source.

Repeatability is best for linear induction motors because they have the fewest moving parts, electrical configuration is simple, and force is constant at every position. Solenoids are similar, except for the change in magnetic path. However, repeatability is good if load and ambient temperature stay constant. Screw actuators have mechanical linkages and friction-sensitive parts and variations in load or temperature affect repeatability. Cylinder response is dependent on fluid temperature, valving, pressure regulation, filters and piping, and precise repeatability is more difficult to obtain.

Broad adjustment of force is easiest in fluid systems because pressures are

power actuators

STROKE AND POSITION		SPEED				SIZE	POWER	COST
RANGE, IN.	POSITION-HOLDING	RANGE, IN./SEC	QUICKNESS OF INITIAL RESPONSE (RELATIVE)	UNIFORMITY OF INITIAL RESPONSE	EASE OF ADJUSTMENT OF SPEED	(RELATIVE)	SOURCE AND AUXILIARIES	AVG INSTALLED (INCL. CONTROLS BUT NOT POWER SOURCE)
0-4	REQUIRES FIXED STOP FOR CLOSE POSITIONING	100	1	4	4	4	CONVENTIONAL ELECTRIC POWER	10-100
0-12	REQUIRES FIXED STOP FOR CLOSE POSITIONING	0-100	1	1	3	4	CONVENTIONAL ELECTRIC POWER	30-100
0-18	REQUIRES FIXED STOP FOR CLOSE POSITIONING	20-100	5	6	2	2	FLUID SUPPLY SYSTEM	75-300
0-10	HOLDS ANY GIVEN POSITION	0-20	4	5	1	1	FLUID SUPPLY SYSTEM	100-500
0-12	HOLDS ANY GIVEN POSITION	0.05-0.4	2	2	6	3	CONVENTIONAL ELECTRIC POWER	500-800
0-12	HOLDS ANY GIVEN POSITION	0.02-0.5	3	3	5	3	CONVENTIONAL ELECTRIC POWER	300-800

readily regulated. The same is true to a lesser extent for linear induction motors and solenoids—voltage is adjustable. Screw actuators driven by induction motors are designed for a given voltage, speed and load; speed and force variation is more difficult.

Reversibility is inherent in cylinders, screw actuators, and linear induction motors: you just reverse the pressure or phase relationship. Solenoids work in one direction only and a return spring or a second solenoid is needed for reversing.

Stroke and position—Only the solenoid is limited in length of stroke; the airgap cannot be excessively large. All other actuators, in theory, can have any desired stroke. Position-holding is another matter; each actuator has unique advantages and limitations. For holding at constant force in any stroke position—useful in remote clamping of parts—choose linear induction motors or fluid cylinders.

Motor-driven screws will hold in any position, but they are designed to hold at a constant position rather than with a constant force. Solenoids are designed for holding at the closed-airgap position only; there the magnetic path is complete and coil impedance is high enough to limit coil

EXAMPLE 1

POSSIBLE ACTUATORS

Job requirements	Linear Motor	Pneumatic Cylinder
Output force, lb 15	✓	✓
constant		
adjustable		
repeatable ✓	1	4
reversible		
Stroke, in. 6	✓	✓
hold end position		
intermediate		
Speed, in./sec 36	✓	✓
fast response ✓	1	5
uniform response ✓	1	6
adjustable speed		
Size important		
Power source any	electrical	electrical & pneumatic
Cost important ✓	2	3

EXAMPLE 2

POSSIBLE ACTUATORS

Job requirements	Pneumatic Cylinder	Hydraulic Cylinder	Screw Type
Output force, lb 300	✓	✓	✓
constant			
adjustable			
repeatable			
reversible			
Stroke, in. 4	✓	✓	✓
hold end position			
intermediate ✓		✓	✓
Speed, in./sec 0.05		✓	✓
fast response ✓	5	4	3
uniform response ✓	6	5	3
adjustable speed			
Size important			
Power source Any	electrical & pneumatic	electrical & hydraulic	electrical
Cost important ✓	3	4	5

current. Ordinary ac solenoids will burn out if operated at an intermediate position—coil impedance is low, currents excessive.

For locking-in at any given position, the motor-driven screw is best. The motor simply is de-energized and its shaft braked; no further actuator output movement is possible. Hydraulic cylinders will also lock-in if the control valves are closed, but leakage may allow drift. Air cylinders and linear motors cannot be locked-in except by physical stops.

Speed—The solenoid is a high-velocity actuator with speed limited only by the mass of the plunger, output force, stroke length and applied load. The tabulated speed is representative of the group but values vary so widely that they are not generally given.

Linear motors and air cylinders can move rapidly. (One 3-phase linear motor has a synchronous speed of about 160 in./sec). Air cylinders are fast because air expands rapidly into the cylinder when the valve is opened and pressure is available. Hydraulic cylinders are limited in speed by pump and valve capacity; screw actuators are limited by drive motor speed and the gear reduction from motor to screw (linear forces are generally high, movement slow).

Quickest initial response is with a linear induction motor. At the instant of switching (within 6 millisec and faster in some cases) maximum accelerating force is applied to the rod. A solenoid also responds instantly to the switching signal, but reaches maximum accelerating force at the end of its stroke. Cylinders and screw actuators have valving, flow or transmission systems which increase response time.

Uniformity of response, just as repeatability, depends on simplicity of configuration. A linear induction motor, for example, repeats within 1 millisec of response time. Ease of speed adjustment is governed by the same factors as adjustment of force, discussed above.

Size—Relative size is based on equivalent force × stroke. High-pressure hydraulic and pneumatic cylinders provide the greatest total energy in least space. Screw-type actuators can have high ratio of force to size, but at the expense of speed. Solenoids and linear motors are relatively bulky, but require no external pumps and valves as do cylinders, and can move much faster than screw actuators.

Power source and auxiliaries—Over-all size, cost, and efficiency depend on supply energy as well as on the actuator design. Electrical actu-

ators use energy more efficiently; fluid actuators are less efficient because the fluid must be pressurized externally, kept pressurized constantly, and throttled to the desired pressure and flow. However, efficiency may be of secondary importance.

Cost—Values in the table are approximate and assume necessary control valves, switches, fittings, and gages, but not the main piping, pumps, and generators. An interesting way to compare costs is this: multiply speed, in./sec, by actuating force, lb, and divide by installed cost. This gives a rough indication of peak energy rate per dollar. The solenoid and linear induction motor rate well by this standard. Another way to figure cost is total energy (force × stroke) per dollar. Then the long-stroke, high-force actuators have the advantage. In most cases cost comparison will be of secondary importance.

Examples using selection method

1—Problem: Actuator for automatic assembly machine to remove rejected assemblies.

Stroke—6 in.
Work per stroke—9 in.-lb
Rate—3 strokes/sec

Solution: Convert values to performance-table units (three 6-in. strokes/sec are equivalent to an avg speed of 36 in./sec; 9 in.-lb work in 6 in. requires an average force of 1.5 lb). Performance table shows that solenoid stroke is too short and screw actuator moves too slowly. Linear induction motor and pneumatic cylinder will both meet the requirements, but the motor has several advantages and is the first choice.

2—Problem: Actuator for remote holding at controllable positions.

Stroke—4 in.
Force—300 lb
Speed—0.05 in./sec

Solution: Solenoid and induction motor cannot meet force requirements. Pneumatic cylinder will not hold accurately at intermediate positions. Choice is between hydraulic cylinder and screw actuator, and will depend on compatibility with other elements on the machine.

3—Problem: Actuator to drive selector on sorting device with 5 selectable positions at 0.5-in. increments, and hold for 0.13 sec at each position.

Stroke—2 in. max
Force—5 lb
Rate—5 random positions/sec minimum

Solution: No standard actuator will hold at intermediate positions and reach the required speed. Present the problem to appropriate manufacturers for possible custom design or modification.

EXAMPLE 3

POSSIBLE ACTUATORS

Job requirements	Linear motor	Screw type	Hydraulic cylinder
Output force, lb 5	✓	✓	✓
constant			
adjustable			
repeatable			
reversible			
Stroke, in. 2	✓	✓	✓
hold end position			
intermediate ✓		✓	✓
Speed, in./sec 30	✓		
fast response ✓	✓	✓	✓
uniform response ✓	✓	✓	✓
adjustable speed			
Size important			
Power source any	electrical	electrical	electrical & hydraulic
Cost important ✓			

Editor's note: Linear power and control actuators have been the subject of these previous PE articles:

Selecting Solenoids, May 23 '60, p 50—Describes all linear and rotary types and outlines a selection procedure.

Flat-armature Motors. Aug 14 '61, p 12—A British laboratory is developing a linear induction motor made with a flat-strip armature to operate continuous conveyors.

High-force Thermostatic Actuators, July 11 '60, p 74—Heat applied electrically to a trapped hydrocarbon wax can operate this linear actuator. Compared with the wax-type are conventional bellows actuators and a rod-and-tube differential expansion device.

Regulate the Exhaust on Air Cylinders, July 31 '51, p 42—Two-way, two-force actuation is possible using novel valving and piston design. It can be done by increasing rod size to lower the effective pressure acting on return stroke; or with relief valves to control exhaust pressure.

When Pistons Need Brakes, Feb 3 '58, p 56—Binary piston, hydraulic-motor-screw actuator and other linear actuators are described, and braking methods are given.

Linear Motion in Sealed Systems, Nov 21 '60, p 100—Canned motor-screw and magnetic jack are described. Application is nuclear.

How To Design With Precision Ball Screws, Apr 24 '61, p 59—Continuous recirculating balls, rolling in helical grooves, reduce friction in motor-driven screw actuators.

Rotary to Linear Motion, Mar 2 '59, p 64—Has sketches of 20 mechanical devices to convert rotary motion of a cam, roller or link into straight-line motion.

Angle and Position-measuring Transducers, Aug 21 '61, p 33—Mechanical, electrical and optical devices are sketched and described—most can be attached directly to actuators.

Look for a future roundup on all common rotary and linear control actuators, plus a special story on how to predict the dynamic behavior of solenoids under varying conditions of load, temperature and voltage.

—F D Yeaple

Plan projects scientifically with

Critical-path scheduling

To hit your target date without paying crash-program prices, focus first on the important jobs.

CHARLES J LYNCH, associate editor

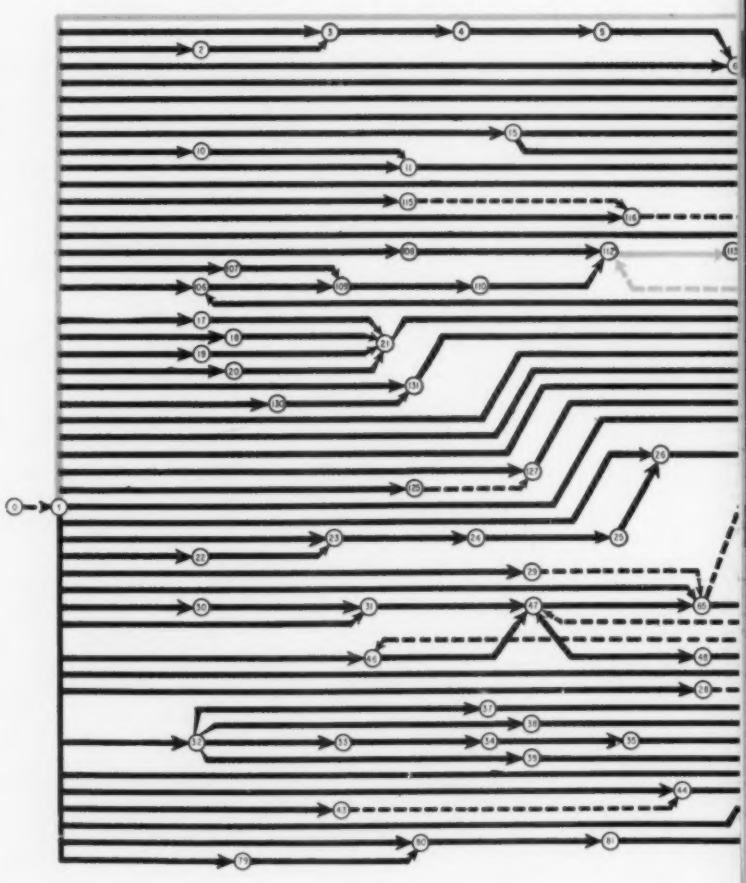
Diagram your project this way to discover four benefits

First, the relationship between jobs is clearly evident. Each arrow represents a job; each circled number a completion point. All jobs preceeding a circled number must be finished before following jobs can be started. Dashed arrows (dummy jobs) show that job at the tail of the arrow must be completed before starting job at the head of the arrow.

Second, you can quickly estimate how long the project will take. Working with a table of normal time estimates for each job, find the path through the diagram (the colored line) that represents the greatest total time. This is the critical path.

Third, trimming time from the project is simply a matter of trimming time from jobs on the critical path. Of course, if you shorten a critical job too much its time may be less than a parallel noncritical job. Now you've got a new critical job. Although it gets a trifle complicated (and here's where computers come in), you can continue to shorten critical jobs—and noncritical jobs as they become critical—until the project is reduced to minimum time.

Fourth, you save money because, even with this "shortest possible" schedule, many jobs proceed at a normal pace and at normal cost.



A "CRASH" program is traditionally just what its name implies—a dizzying plunge through the stratosphere of cost-plus contracts, doubled manpower requirements and overtime schedules, all of which comes to an abrupt and noisy conclusion against the unyielding commitment of a firm deadline date.

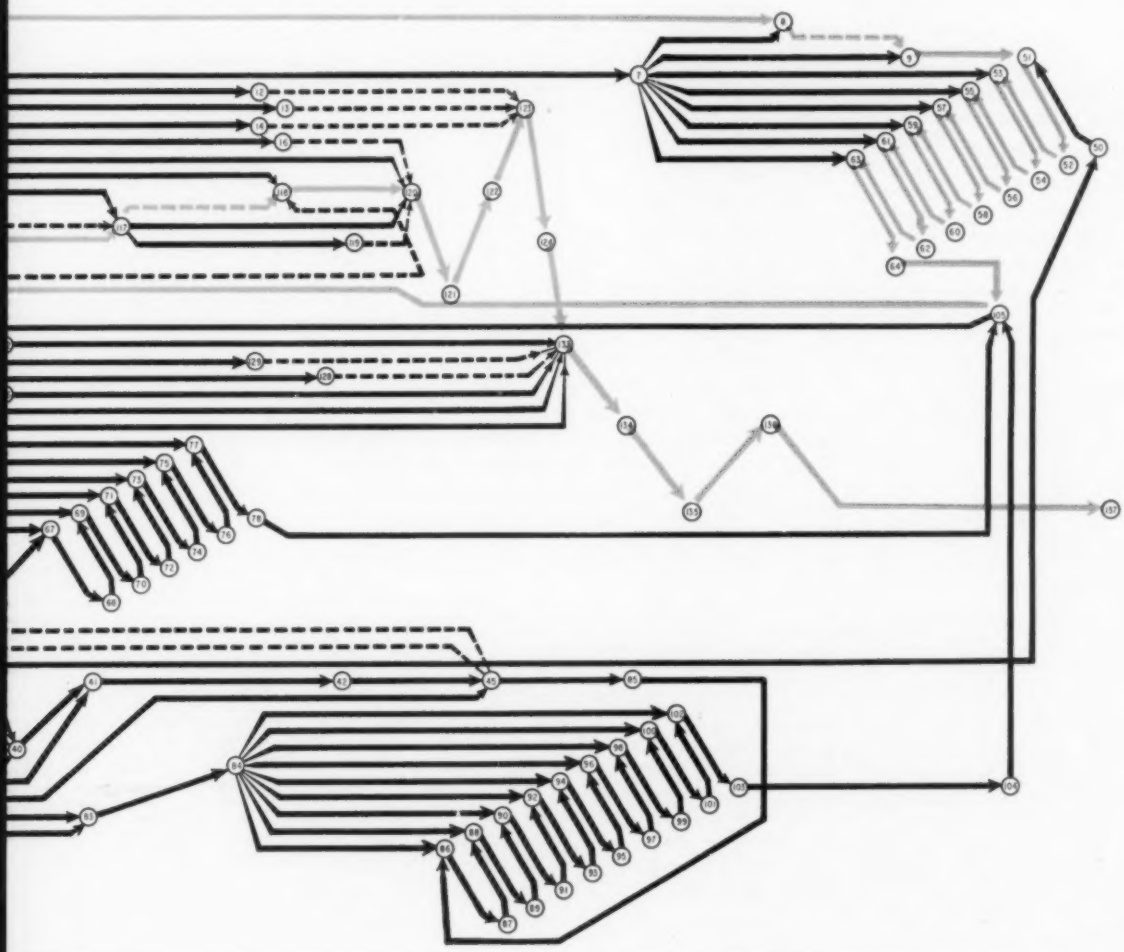
A better solution is provided by a new tool called Critical-path Scheduling (also known as the Critical-path Method or CPM). It is based on the seemingly obvious idea that the time needed for the whole project depends on the sum of times needed for only a small number of essential jobs (usually less than 20% of the total); speeding up the other jobs does nothing to hasten the completion date. By concentrating on these critical phases of a project, the reasoning continues, you will get the same result as an across-the-board crash program without paying an across-the-board cost penalty.

The scheduling procedure that evolved from this kind of reasoning is, today, more than an idea. Beginning with a trial run at DuPont's Louisville plant in 1957 (where it saved an estimated $1 million a year) it has since proven its usefulness in construction work, maintenance and plant improvement. A somewhat simplified scheme called PERT (for Program Evaluation and Review Technique) helped to expedite the Polaris program. And the Air Force uses a similar project-monitoring method called PEP (Program Evaluation Procedure).

The key to the critical-path method is a graphical plot, called an arrow diagram, which shows each phase of the project and its relationship to other phases. Like a Gantt chart (see *PE—Nov* 4 '57, *p* 34), the arrow diagram allows you to arrange the individual jobs and, based on the time required for each, you can estimate how long the project will take. But the arrow diagram goes further than this. With this new method of plotting, you can easily spot the critical jobs—those that will delay the whole project if they are delayed—and concentrating on these, you can decide where to speed it up and what it will cost.

The first step in the critical-path method is to list all the jobs that have to be done to complete a project. These will probably be listed roughly in sequence, but the order isn't important at this stage. Include only

of the critical-path method



How to schedule a small design

FOR this example, we've chosen a gearbox—actually, the scheduling ot a prototype gearbox for a new machine tool. The diagram is simple, there is no need for a computer, but the steps in the critical path method are the same no matter how large or small the project.

Here's how it's done:

The project engineer starts with the gearbox specification prepared by the machine design group. Drawing on his experience with similar projects, he lists all the jobs that need to be done to deliver an assembled unit meeting these specifications. The list contains 15 jobs. He then calls in his chief designer, drafting-room supervisor and shop foreman, and they estimate time and cost of each job on both a normal and "crash" basis. In making the estimates for crash time and cost, they consider such expediting measures as overtime work, hiring additional manpower, and subcontracting special jobs.

The next step is to prepare the arrow diagram. The first job is obviously "design," so an arrow is drawn to represent this. This is followed by three jobs, all of which can be started as soon as the design is complete: (B) drafting, (D) ordering special materials, (E) ordering bearings, oil seals and other purchased parts. Three arrows sprouting from the head of the first show this relationship. Shop work can't begin until the drawing is checked and special materials arrive, so both these arrows terminate at the beginning of the shop work (4).

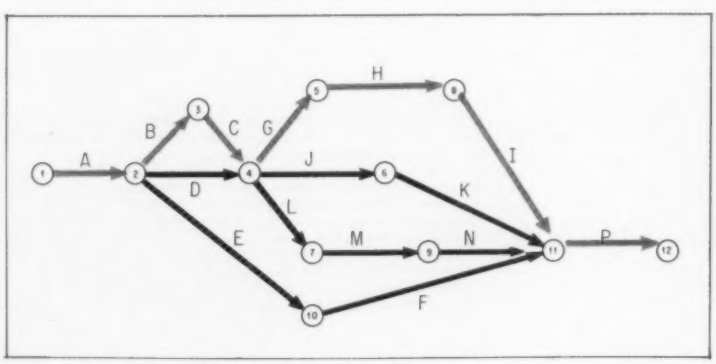
	Normal			Crash		
	Time, Weeks	Total Float, Weeks	Cost, $	Time, Weeks	Cost, $	Cost Slope, $/week
A Design	2.5	0	450	1.5	700	250
B Drafting	0.8	1.0	140	0.5	200	200
C Check drawing	0.2	1.0	35	0.1	45	100
D Deliver special materials	2.0	0	10	1.0	30	20
E Deliver bearings, oil seals	1.5	3.3	10	0.5	20	10
F Inspect purchased parts	0.1	3.3	20	0.05	25	100
G Pattern for housing	2.3	0	350	1.3	550	200
H Cast housing	0.2	0	50	0.1	75	250
I Machine housing	0.4	0	100	0.3	150	500
J Turn shafts	0.8	1.8	175	0.3	375	400
K Heat treat shafts	0.3	1.8	75	0.3	75	...
L Machine gear blanks	0.8	0.6	175	0.4	325	375
M Cut gears	1.0	0.6	250	0.5	450	400
N Heat treat gears	0.5	0.6	125	0.5	125	...
P Assemble	2.0	0	300	1.0	600	300
			2265		3745	

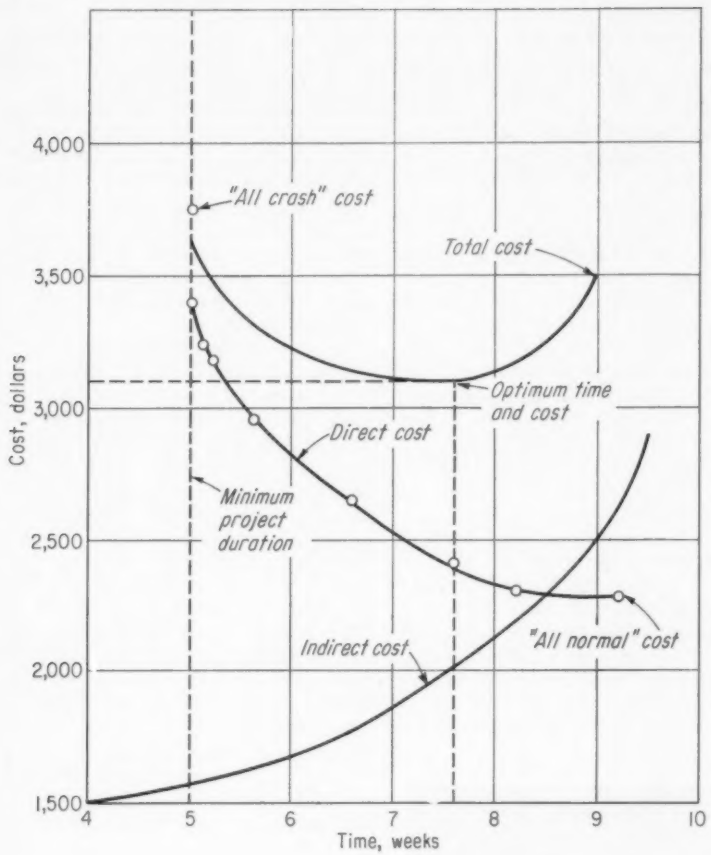
Shafts, housing and gears can all be made during the same time interval so these are shown as parallel arrow paths. All arrows terminate at the beginning of the assembly phase where they meet the arrow representing delivered and inspected purchased parts.

Now, referring to the normal job times previously agreed upon, it is easy to establish the critical path—the one requiring greatest total time. And these critical times tell how much float is available in parallel paths.

The project engineer is now ready to estimate how much time he can squeeze out of the project and what it will cost. Subtracting crash time from normal time and normal cost from crash cost and dividing the two gives him the cost slope which he enters as another column of the table. This is a measure of how costly it will be to speed up each job. Looking first at the job with zero float and lowest cost slope, and then moving on to more expensive critical jobs, he finds his expediting steps break down like this. (For purposes of computation—though this may not be true in practice—he assumes that it is possible to expedite a job to any desired point between the normal and crash times at a pro rata portion of the cost for an all-out crash program on that job.)

• The least expensive critical job is D. Because of the allowable float in parallel jobs B and C, he can cut **one week** at a cost of $20. Now B, C and D are all critical. But no more time can be pared from these





because D has already been reduced to the allowable minimum.

- He can save **0.6 weeks** by speeding up G. This costs him (0.6) (200) or $120. He could have saved a full week but there is only 0.6-week float in jobs L, M and N. With this compression, G is still the least expensive critical job. But to cut any more from G, he would have to cut an equal amount from L (the least expensive job in the parallel critical path) at a cost of $200 + $275 = $575 per week.

Continue to shave time from critical jobs and re-examining non-critical jobs as they become critical, he finds he can save

- **1 week** in A at a cost of $250
- **1 week** in P at a cost of $300
- **0.4 weeks** by trimming G and L at a cost of 0.4 (575) = $230
- **0.1 weeks** by compressing H and M at a cost of 0.1 (650) = $65
- **0.1 weeks** by expediting I and M at a cost of 0.1 (900) = $90

At this point the project has been reduced to the minimum. Total time is 5 weeks, which is equal to the time of an "all-crash" project. But total cost is $3340 compared with $3745 for the "all-crash" project.

The curve above shows the relationship between project cost and time. This is combined with the curve for indirect project costs, using the established overhead figures for the departments involved. The total cost curve has a minimum point at 7.6 weeks, meaning he can produce the gearbox at minimum cost by expediting jobs D and G while allowing the other jobs to proceed on a normal schedule. This adds only $120 to the direct cost.

those jobs that are directly related to the project but don't be disturbed if the list gets long and cumbersome; the diagramming will straighten out the mess (it can handle as many as 1000 jobs if necessary).

To make the diagram, begin with the job that must be done first and draw an arrow to represent it. The length and direction of the arrow aren't important, although this first arrow will probably be a horizontal one pointing to the right. Now ask yourself which job follows the first job and whether there are other jobs that can be done at the same time. Draw an arrow (or arrows) to indicate this second job starting from the head of the previous arrow and pointing in whatever direction is convenient to provide space for other arrows. Jobs that can be done at the same time are drawn in parallel, like an electrical circuit, while jobs that must follow one another are drawn in series. If a job on one parallel path must be done before another job on another parallel path, show this relationship with a dotted arrow from the head of the first job to the tail of the second. Continue drawing arrows, working from left to right, until all jobs are represented.

What you have constructed is a progress chart—what must precede each job, what must follow it, and what can be done at the same time. Though its real usefulness is not yet evident, it has already yielded one important benefit: Because you were forced to think in terms of what must be done at what time, you have had to include every phase of the project.

Now go back to the list of jobs and add the time required to complete each. These time estimates are usually based on previous experience with similar jobs. If there is difficulty getting a reliable time estimate, try dividing the job into several smaller tasks for which more accurate estimates are available. Or, for research and development work, you might make three estimates—an optimistic one, a pessimistic one and a "most likely" one—combining them statistically to give an estimate which reflects a 50% probability that the job will be completed within the estimated time. Make all estimates, including the combined, three-level estimates, on the basis of normal working effort. Ignore speedup measures such as overtime or additional facilities and personnel for the moment.

With these time estimates in one hand and the arrow diagram in the other, you can quickly find the critical jobs. Trace a path through the diagram from left to right and add the

time for each job on the path. Repeat this for all possible paths; the one with the longest time is the critical path and the jobs on it are the critical jobs. Tracing all possible paths through the diagram may sound like tedious work but it's actually much simpler than it looks. Even a complicated diagram can usually be divided into several smaller diagrams which are then attacked individually.

Notice that by defining the critical path you have eliminated from consideration a large number of noncritical jobs. Rushing these jobs can have no effect on the completion date for the project. Even a delay, providing it does not exceed that of the parallel critical jobs, will have no effect. The leeway between the time required for the critical jobs and the time required for noncritical jobs is called "float." If several series-connected, noncritical jobs are in parallel with the critical path, the amount of float assignable to any particular job will depend on when the preceding and following noncritical jobs are scheduled. For purposes of tabulation, the usual practice is to make all the float available to each series-connected job and decide how it will be divided later.

It is clear that to speed up a project, the critical jobs—those that have zero float—will have to be expedited. And the least expensive way to do this is to start with the jobs that cost least to expedite per unit time. From the table of time estimates, make an estimate of the total direct cost of each job assuming normal work effort. Then add another column to show the cost and time required if the job is done on a crash basis. Combining these four columns gives the cost slope—the cost increment divided by the time increment.

The table is your guide to compressing the project's schedule. Find the job that has zero float and the lowest cost slope. If this job is done on a crash basis, the length of the project will be reduced accordingly and its cost will go up by an amount equal to whatever it costs to "crash" this one job. Remember, however, that compressing one job may cause parallel jobs to go critical. Also notice that the over-all time saved by crashing a particular job can be no more than the available float.

For a project of practical size (say 100 jobs or more) you will need to draw up a new table for each reduction in project length. Otherwise, after one or two compressions, it will be difficult to tell which jobs are critical, which jobs have been compressed to the minimum, and how much float is available. By continuing to shave time from the critical jobs, starting with the least expensive and working up, you can eventually pare the project to minimum length (equal to the "all crash" project length).

The sum of job costs—whether crash or normal—for the minimum length project is the most that needs to be spent. Notice that it is (probably) less than the cost of the "all-crash" program.

Direct project costs are not the whole story, however. There are also indirect costs or overhead (the cost of staying in business) and these must be added to the project cost. Generally, overhead increases directly with time, in contrast to direct costs, which decrease with time. These relationships emphasize the importance of preparing a complete direct project cost curve, from maximum time, minimum cost to minimum time, maximum cost. Adding the direct cost curve to the indirect cost curve gives a total cost curve that usually has a minimum point. This represents the least expensive schedule for the project.

Though the critical-path method will handle projects of almost any size, the tedious hand work required for a large project is more than most scheduling staffs would be willing to bear. This is particularly true for schedules that need continual revision (and even the best schedules do) to meet changes in cost and time as work proceeds. For these detailed calculations and recalculations, a computer is the only answer.

Rear Adm. William F Raborn, head of Special Projects Office of the Navy, is chief promoter for PERT (the Navy's version of the critical path method). His insistence on using this method for scheduling the fantastically complex Polaris missile and submarine program was responsible for this weapons project being completed two years ahead of schedule.

Several computer programs are presently available for the purpose. IBM has a program called LESS (Least cost EStimating and Scheduling). Sperry-Rand has a critical-path scheduling program for their Univac computer in addition to PERT and PEP programs, and Burroughs is working on a PERT program for their new B-5000 system. RCA recently announced a PERT program which they have used on their own scheduling problems and are now prepared to offer for general use. One of the most recent additions to the group is GE's CPM program for use on their 225 general-purpose computer.

Besides eliminating paperwork, computers offer other advantages. Time saving is, of course, one of them. With a computer spewing out new and revised schedules, management can stay on top of the project and head off potential problems before they get costly. Moreover, a computer can digest more information than its human counterpart and give answers in more detail. The GE program, for example, has provision for a priority weighting function that can be applied to each job. With this feature, noncritical jobs can be scheduled at a time that best suits the available resources and facilities by appropriate asignment of float.

Even more sophisticated developments are on the way. It is expected that there will soon be a method for scheduling several projects at once, interlacing them to make best use of the available equipment and personnel. Also, work is being done to combine the critical-path method with other modern management tools. Mathematical simulation, for example, could be used to examine particular parts of the critical path in detail.

For **Reprint** of above article, just check 631 on one of the Reader Service cards found in this issue.

Editor's Note: To compare this method with traditional, but less powerful, scheduling procedures see:

How You Can Buy Time, April 7 '58, p 32—How to compress your schedule to get a new product on the market faster.

Cost of Research and Development, Mid-Oct '55, p A9—How Gantt charts and graphs help to estimate costs.

Keeping Track of Projects with Control Boards, Sept '53, p 141. These graphical aids save time and show up-to-the-minute status of each project.

Use matrix arithmetic

To find gear ratios

A good way to start using this new mathematical tool is to apply it to an old problem which has never really had a satisfactory solution.

ARNE BENSON, staff consultant, Sanders Associates Inc., Nashua, N. H.

FINDING suitable change gears for a specified ratio is actually two problems in one: 1) find a rational number N/D close enough to the specified ratio R; 2) factor N and D into acceptable gear-tooth numbers. The first part of this problem has received a great deal of attention while the second part still must be solved by the cut-and-try method, or by reference to factor tables.

Matrix arithmetic offers a systematic way to determine all fractions within specified limits of a given ratio. It converges rapidly to the region in which R lies; it is not subject to cumulative error; and it is easily arranged for paper-pencil, desk calculator or computer work.

The method is based upon conjugate fraction theory which states that two fractions a/b and c/d *are* conjugate if $(ad - bc) = \pm 1$. This means that between two conjugate fractions there exists no other fraction with smaller numerators or denominators. In this sense each conjugate fraction is "a best approximation" of the other. If the numbers a and b are chosen so that a/b is a fraction in lowest terms greater than the desired ratio R, and if c and d are similarly chosen so that c/d is a fraction in lowest terms less than the desired ratio R, the basic matrix can be formed:

$$B = \begin{vmatrix} a & c \\ b & d \end{vmatrix}$$

In matrix theory B is unimodular if $(ad - bc) = 1$.

A multiplier matrix is now needed and can be formed from the unit matrix:

$$X = \begin{vmatrix} 1 & 0 \\ 0 & 1 \end{vmatrix}$$

SYMBOLS

G, B, X	—2 row unimodulator matrices
B^{-1}	—is inverse of B matrix
G^*, X^*	—are preliminary matrices used to determine desirable X matrix that is unimodular
R	—gear-train ratio
N	—numerator of R
D	—denominator of R
a, b, c, d	—elements of B matrix, positive integers
a/b and c/d	—gear ratios taken from standard tables

by adding adjacent row elements and interposing their sum:

First stage $\begin{vmatrix} 1 & 1 & 0 \\ 0 & 1 & 1 \end{vmatrix}$

Second stage $\begin{vmatrix} 1 & 2 & 1 & 1 & 0 \\ 0 & 1 & 1 & 2 & 1 \end{vmatrix}$

Third stage $\begin{vmatrix} 1 & 3 & 2 & 3 & 1 & 2 & 1 & 1 & 0 \\ 0 & 1 & 1 & 2 & 1 & 3 & 2 & 3 & 1 \end{vmatrix}$

This is a new concept in matrix arithmetic which was specially developed by the author to solve gear ratios. Note that:

- The unit matrix can be expanded indefinitely;
- When regarded as a fraction each column is in lowest terms;
- The fractions follow a descending order;
- Each adjacent 2×2 sub-matrix is unimodular;
- No fraction with smaller terms exists with value between adjacent fractions.

These unique properties of the multiplier matrix can be used to find the specified ratio R which lies between the two ratios in the basic matrix by multiplying the two matrices: $BX = G$.

To show how this works in a practical way, suppose

$$R = 1/\sqrt{\pi} = 0.564{,}189$$

is to be approximated within $\pm$ 0.000,02. From gear ratio tables select

$$a/b = 35/62 = 0.564{,}516$$
$$c/d = 22/39 = 0.564{,}102$$

Since $35 \times 29 - 22 \times 62 = 1$

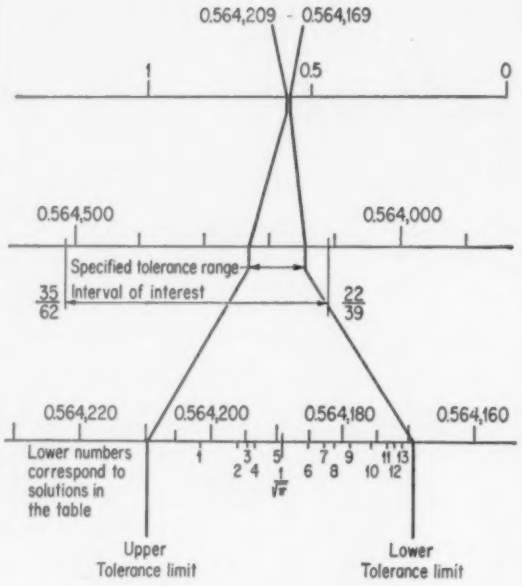
the basic matrix is unimodular, and it can be multiplied by the X matrix to give:

Unit Matrix: $\begin{vmatrix} 35 & 22 \\ 62 & 39 \end{vmatrix} \times \begin{vmatrix} 1 & 0 \\ 0 & 1 \end{vmatrix} = \begin{vmatrix} 35 & 22 \\ 62 & 39 \end{vmatrix}$

First stage: $\begin{vmatrix} 35 & 22 \\ 62 & 39 \end{vmatrix} \times \begin{vmatrix} 1 & 1 & 0 \\ 0 & 1 & 1 \end{vmatrix} = \begin{vmatrix} 35 & 57 & 22 \\ 62 & 101 & 39 \end{vmatrix}$

continued, next page

Matrix arithmetic magnifies tolerance limits



Solution No.	Decimal Equivalent	Ratio	Factors
	0.564,209	Upper Tolerance Limit	
1	0.564,202	145/ 257	257 is prime
2	0.564,197	457/ 810	457 is prime
3	0.564,195	312/ 553	$2^3 \cdot 3 \cdot 13/7 \cdot 79$
4	0.564,193	479/ 849	479 is prime
5	0.564,189	167/ 296	167 is prime
6	0.564,185	523/ 927	523 is prime
7	0.564,183	356/ 631	631 is prime
8	0.564,182	545/ 966	$5 \cdot 109/2 \cdot 3 \cdot 7 \cdot 23$
9	0.564,179	189/ 335	$3^3 \cdot 7/5 \cdot 67$
10	0.564,176	589/1044	$19 \cdot 31/2^2 \cdot 3^2 \cdot 29$
11	0.564,174	400/ 709	709 is prime
12	0.564,173	611/1083	$13 \cdot 47/3 \cdot 19^2$
13	0.564,171	211/ 374	211 is prime
	0.564,169	Lower tolerance limit	

Second stage:

$$\begin{vmatrix} 35 & 22 \\ 62 & 39 \end{vmatrix} \times \begin{vmatrix} 1 & 2 & 1 & 1 & 0 \\ 0 & 1 & 1 & 2 & 1 \end{vmatrix} =$$

$$= \begin{vmatrix} 35 & 92 & 57 & 79 & 22 \\ 62 & 163 & 101 & 140 & 39 \end{vmatrix}$$

Third stage:

$$\begin{vmatrix} 35 & 22 \\ 62 & 39 \end{vmatrix} \times \begin{vmatrix} 1 & 3 & 2 & 3 & 1 & 2 & 1 & 1 & 0 \\ 0 & 1 & 1 & 2 & 1 & 3 & 2 & 3 & 1 \end{vmatrix}$$

$$= \begin{vmatrix} 35 & 127 & 92 & 149 & 57 & 136 & 79 & 101 & 22 \\ 62 & 225 & 163 & 264 & 101 & 241 & 140 & 179 & 39 \end{vmatrix}$$

The desired ratio lies between 101/179 and 22/39 so further effort needs to be concentrated only in this area of the G matrix. This can be done by expanding the lower portion of the X matrix to give:

$$X = \begin{vmatrix} 1 & 2 & 1 & 1 & 0 \\ 3 & 7 & 4 & 5 & 1 \end{vmatrix}$$

Multiplying this with a portion of the B matrix gives:

$$BX = G$$

$$\begin{vmatrix} 101 & 22 \\ 179 & 39 \end{vmatrix} \times \begin{vmatrix} 1 & 2 & 1 & 1 & 0 \\ 3 & 7 & 4 & 5 & 1 \end{vmatrix} = \begin{vmatrix} 101 & 224 & 123 & 145 & 22 \\ 179 & 397 & 218 & 257 & 39 \end{vmatrix}$$

It appears now that $145/257 = 0.564,202$ is acceptably close to the specified R. Unfortunately, 257 is a prime number and it cannot be factored into suitable sets of change gears.

To proceed from here the lower portion of the X matrix

$$\begin{vmatrix} 1 & 1 & 0 \\ 4 & 5 & 1 \end{vmatrix}$$

can be expanded further and the resulting X matrix can then be multiplied:

$$\begin{vmatrix} 123 & 22 \\ 218 & 39 \end{vmatrix} \times \begin{vmatrix} 1 & 2 & 1 & 1 & 0 \\ 4 & 9 & 5 & 6 & 1 \end{vmatrix} = \begin{vmatrix} 123 & 268 & 145 & 167 & 22 \\ 218 & 275 & 257 & 296 & 39 \end{vmatrix}$$

This might yield a favorable ratio.

A second alternative is to select one or two new B matrices from the above G matrix and multiply them by an expanded unit matrix to give:

$$\begin{vmatrix} 123 & 145 \\ 218 & 257 \end{vmatrix} \times \begin{vmatrix} 1 & 2 & 1 & 1 & 0 \\ 0 & 1 & 1 & 2 & 1 \end{vmatrix} = \begin{vmatrix} 123 & 391 & 268 & 413 & 145 \\ 218 & 693 & 475 & 732 & 257 \end{vmatrix}$$

or

$$\begin{vmatrix} 145 & 22 \\ 257 & 39 \end{vmatrix} \times \begin{vmatrix} 1 & 2 & 1 & 1 & 0 \\ 0 & 1 & 1 & 2 & 1 \end{vmatrix} = \begin{vmatrix} 145 & 312 & 167 & 189 & 22 \\ 257 & 553 & 296 & 335 & 39 \end{vmatrix}$$

In these multiplications the unit matrix may be expanded to any length necessary to produce a suitable ratio. The example was purposely created to show how the principle works. But a short cut is possible and its practicality can now be more readily demonstrated.

Expansion of tolerances

The problem is to pinpoint the region of the expanded X matrix which will give the specified ratio in the G matrix when the X matrix is multiplied by the selected B matrix. This is done by entering the specified tolerance limits on R in the G matrix (called it G^*). Now, $BX^* = G^*$; or $X = B^{-1} G^*$.

By matrix theory if $B = \begin{vmatrix} a & c \\ b & d \end{vmatrix}$,

then its inverse $B^{-1} = \begin{vmatrix} d & -c \\ -b & a \end{vmatrix}$.

This maintains the unimodular characteristic of the B matrix, which is essential. On the other hand, X^* matrix, which generally is not unimodular must be transformed into X matrix which is unimodular. This can be clarified by applying this basic theory to the original example above:

The specified ratio is $0.564,209 > R > 0.564,169$, and it can be written into the G^* matrix as:

$$G^* = \begin{vmatrix} 0.564,209 & 0.564,169 \\ 1 & 1 \end{vmatrix}$$

Inverting the selected B matrix gives:

$$B^{-1} = \begin{vmatrix} 39 & -22 \\ -62 & 35 \end{vmatrix}$$

Multiplying the above two matrices gives: $X = B^{-1} G^*$

$$X^* = \begin{vmatrix} 39 & -22 \\ -62 & 35 \end{vmatrix} \times \begin{vmatrix} 0.564,209 & 0.564,169 \\ 1 & 1 \end{vmatrix}$$

$$= \begin{vmatrix} 0.004,151 & 0.002,591 \\ 0.019,042 & 0.021,522 \end{vmatrix}$$

Since the columns of the matrices are interpreted as fractions, the above matrix can be transformed to give:

$$X^* = \begin{vmatrix} 0.201,79 & 0.120,39 \\ 1 & 1 \end{vmatrix}$$

This pinpoints the desirable region of the original X matrix which can be used to multiply the original B matrix to give the desired ratios in the G matrix. The region of the X matrix which is equivalent to the above X^* matrix is:

$$X = \begin{vmatrix} 1 & 1 & 1 & 1 \\ 5 & 6 & 7 & 8 \end{vmatrix}$$

Expanding this X matrix a few times and multiplying it by the original B matrix gives:

$$\begin{vmatrix} 35 & 22 \\ 62 & 39 \end{vmatrix} \times \begin{vmatrix} 1 & 3 & 2 & 3 & 1 & 3 & 2 & 3 & 1 & 3 & 2 & 3 & 1 \\ 5 & 16 & 11 & 17 & 6 & 19 & 13 & 20 & 7 & 22 & 15 & 23 & 8 \end{vmatrix} =$$

$$\begin{vmatrix} 145 & 457 & 312 & 479 & 167 & 523 \\ 257 & 810 & 553 & 849 & 296 & 927 \end{vmatrix}$$

$$\begin{vmatrix} 356 & 545 & 189 & 589 & 400 & 611 & 211 \\ 631 & 966 & 335 & 1044 & 709 & 1083 & 374 \end{vmatrix}$$

All of these 13 ratios are within the specified tolerance limits as shown graphically at left. Furthermore, no others exist between these in value that have smaller numerators or denominators. This means that the above G matrix consists of all the best approximations to the specified ratio.

The results can be tabulated as shown at left with the possible change gears indicated in the right hand column. For example, 145,257 can be used if a single mesh is satisfactory. Other ratios can be factored to give the most desirable mesh as shown.

In the event that none of the factored ratios are satisfactory two things can be done: A new B matrix can be selected by choosing two adjacent columns from the G matrix above. Or the X matrix can be further expanded to give more intermediate ratios in the G matrix.

HOW MATRIX ARITHMETIC IS USED

A Matrix is a rectangular array of numbers. In this application only 2-row matrices are used.

Matrices can be added, multiplied and raised to a power. Equations can be written with matrices as terms.

Multiplication is possible when the first matrix has as many columns as the second has rows. For example, if

$$A = \begin{vmatrix} a & c \\ b & d \end{vmatrix} \text{ and } B = \begin{vmatrix} e & g \\ f & h \end{vmatrix}$$

then their product

$$A \times B = \begin{vmatrix} (ae + cf) & (ag + ch) \\ (be + fd) & (bg + dh) \end{vmatrix}$$

Multiplication is not commutative; that is, the product $A \times B$ does not necessarily equal $B \times A$.

Determinant is a function of a square matrix, which, in the 2×2 case:

$$det. \begin{vmatrix} a & c \\ b & d \end{vmatrix} = (ad - bc)$$

Unimodular matrix has a determinant equal to ± 1. Inverse of a 2×2 unimodular matrix

$$B = \begin{vmatrix} a & c \\ b & d \end{vmatrix}$$

$$B^{-1} = \begin{vmatrix} d & -c \\ -b & a \end{vmatrix}$$

Thus the matrix equation $AX = B$ can be solved for X by finding the inverse of A, then $X = A^{-1} B$.

All rational numbers can be formed by adding adjacent numerators and denominators starting with 1/0 and 0/1. This is the easiest way to find the desirable ratio when the tolerance is wide, but for close tolerance ratios the labor of repeated long division is excessive and the chance of error increases accordingly. Also a single addition error invalidates all that follows.

With a properly formulated matrix equation you can quickly locate the region in which acceptable ratios lie, and they can be readily programmed for either calculator or computer operation. Computationally, it is less subject to error, and, by solving a matrix equation, you identify the tolerance region in one step without involving recurrence processes and continual testing of fractions. Mathematically, the properties of rational numbers is actually just a part of the larger theory of matrices.

EDITOR'S NOTE: For additional information on other methods for calculating change gears see:

"4 Ways to Select Change Gears—and the Faster 5th Way", Feb 15 '60, p 64—Compares new calculator method with four previous methods with a general description of each.

—Frederick Marich

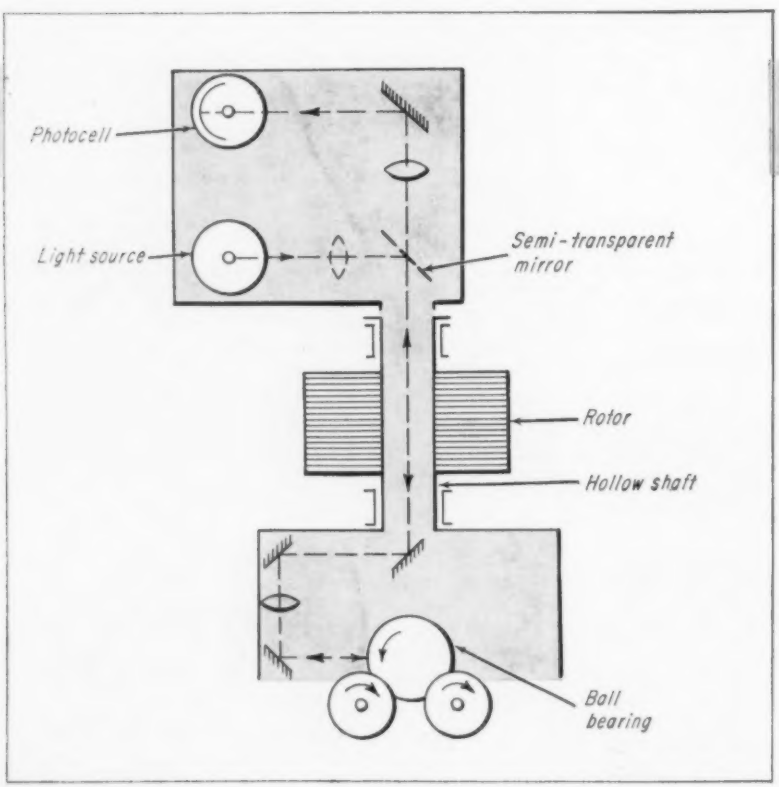
Orbiting light spot

Measures surface finish of bearing balls (9400/hr) to detect imperfections produced by improper pressing, grinding or hardening

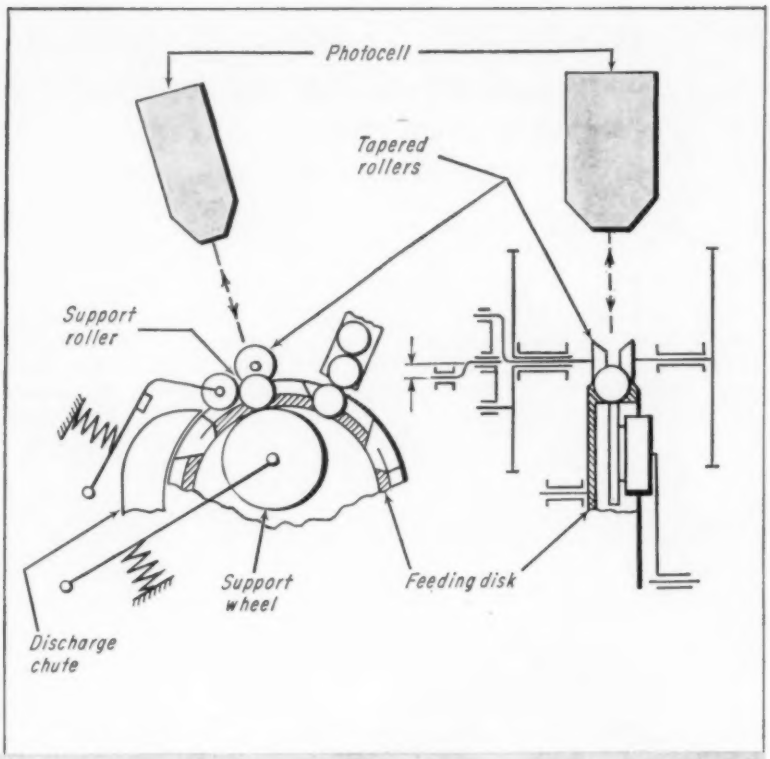
AUTOMATION of bearing ball inspection eliminates a serious bottleneck in ball bearing production. Increased reliability of the checking process is gained by automation since inspection personnel are subject to fatigue, eye strain and errors in judgment. These variables required bearings in some classes to be checked as often as three times to obtain desired tolerances.

Defects in bearing ball surfaces and ball shape resulting from pressing (holes, cracks, or points), grinding (wrong diameter, flat surfaces, grooves) or hardening (incorrect hardening, or basically faulty material) are detected and the ball rejected automatically. Only manual operation required is to load pressed, ground and hardened balls into funnel on top of checker. Automatic feed and forwarding plus collection of rejected balls can be added to incorporate unit into production lines.

Automatic inspector checks bearing balls ranging from 3 to 10 mm (0.117 to 0.390 in.) diameter. The checker measures 24.2 x 19.9 x 63.8 in. weighs 375 lbs and draws 500 watts from a 220-v ac source. The VKK-series Bearing Ball Checkers were shown for the first time this month at the Brno Trade Fair and are marketed by Strojimport, Czech Foreign Trade Corp, Prague, Czechoslovakia.

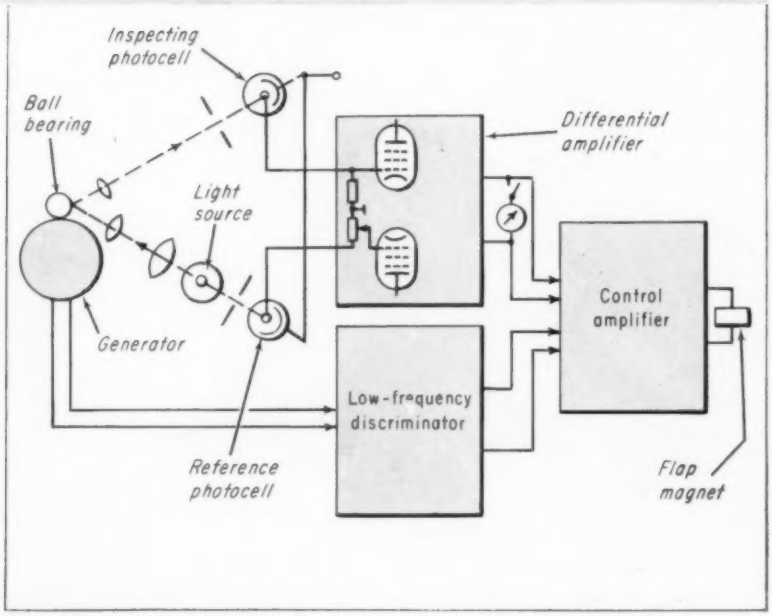


checks bearing balls

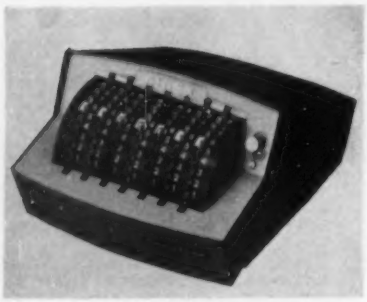


Bearing balls to be inspected are dumped into a hopper on top of checker and from there to the feeding disk which rotates in a horizontal plane. Each ball drops into a slot in the disk and is centered between the tapered rollers, support roller and support wheel. In the inspection position the ball is supported by rollers and support wheel and does not touch the disk. The truncated tapered rollers have a common vertex angle of 90° and a common axis. The righthand roller rotates uniformly but the lefthand roller is accelerated and decelerated during each rovolution. This additional motion is generated by the eccentric lever system to produce a meridional inspection path. As the tapered rollers turn the ball a photoelectric inspection cycle is started by cam-operated contact. At the end of the 0.1-sec inspection cycle, the feed disk indexes to the next ball. Total time for the complete operation is 0.38 sec. The inspected ball is dumped from the feed disk into a discharge chute where sorting flaps, actuated by the inspection circuits, channel the ball into accept or reject hoppers.

Balls with surface impurities or with excessive deformation can retard one of the rolling elements in the checking position. This could result in the nonrotating defective ball being checked out as OK despite a major fault. To prevent this a generator rotor is incorporated in the hub of the support wheel. If the output frequency drops from the selected value, the ball is rejected independent of the photocell check.



The photoelectric circuit of the checker uses two photocells to compare direct and reflected illumination. Light reflected from the ball goes to one photocell while the second receives light directly from the source. Output from the photocells passes through a dc differential amplifier where variations in the reflected light are detected. The control amplifier trips the magnet which actuates the sorting flaps in the discharge chute. The support wheel generator frequency is controlled by a low-frequency discriminator also signaling the control amplifier. This permits inspection for major defects, such as excessive deformation, independent of variations in reflected light.

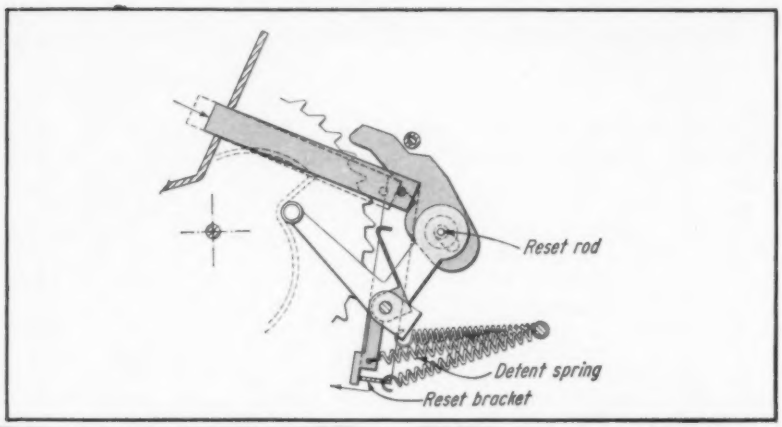


Cut costs out of

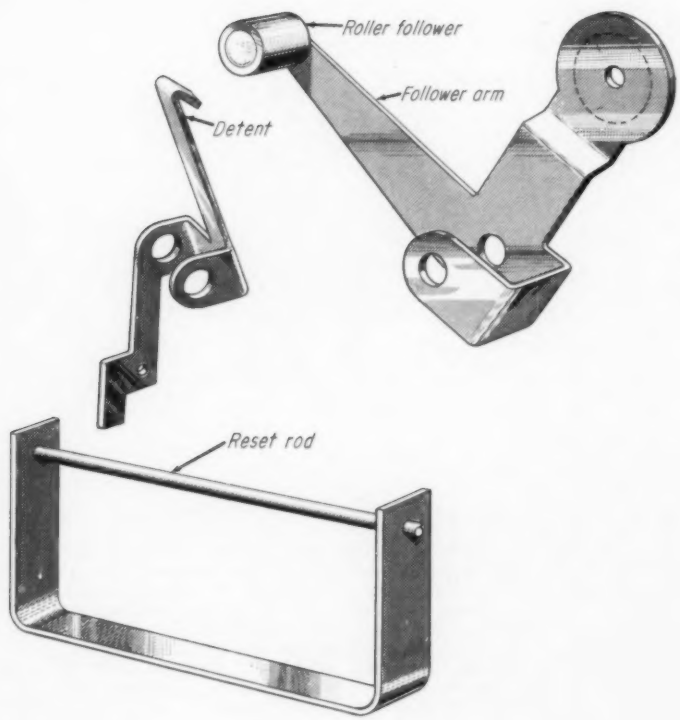
Multifunction injection-molded plastic parts and sheetmetal stampings are stacked on rods to make a simple adding machine.

MACHINE is operated by one finger placed on the sprocket at the desired number and turned down. The sum of successive additions is displayed by numerals which appear at a series of openings on the machine face. By holding an erase button down all numerals automatically return to zero. Repetitive use of plastic and sheet-metal stampings reduce cost of tooling and materials. The Caroline adding machine sells for 100 Swiss francs (approx $23) and is produced by Societe Industrielle des Metaux Manufactures SA, Nyon, Switzerland.

$23 adding machine



To clear the machine reset button is held down until zeros appear in all columns. The reset button pivots a bracket mounted on the follower arm rod which lifts all transfer pawls and at the same time pivots the detents away from the number wheels. The spring-loaded roller followers still lean against the cam lobes. They ride downhill to bring the number wheels back to zero position.



Number wheels add digits, tens, hundreds etc., depending upon which wheel is indexed. Spring loaded detents hold and positively locate number wheel in indexed positions. Each one-piece molded number wheel incorporates a four-lobe cam, each lobe occupying a 90° segment of the wheel. Each wheel has 40 teeth on its circumference so a cam lobe occupies a segment equal to 10 units, 0 through 9.

When the first number wheel is indexed 9 units, the roller following the cam path pivots the follower arm to the rear. This retracts the transfer pawl which is in contact with the next number wheel and the nose of the pawl drops behind the tooth on which it was resting. When the first wheel is indexed one or more additional units the roller passes the cam nose and the spring-loaded follower is forced forward. The transfer pawl advances the next number wheel one unit.

Stacking seven such wheel-pawl mechanisms side by side in an interlocked assembly makes the machine capable of adding to 9,999,999. In production the molded number wheels and stamped pawl mechanisms are assembled on two shafts which support all moving elements of the machine.

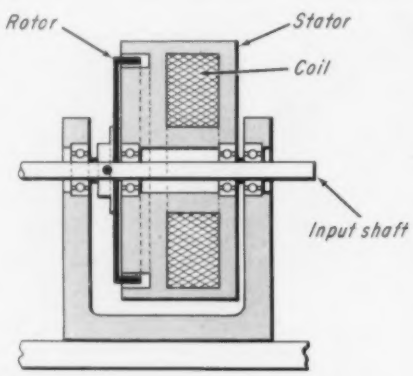
Cascaded springs

Redesigned dual-rotor brake has increased sensitivity and improved high-speed performance. Interlocked torque springs shift ranges automatically.

ACTUALLY a highly sophisticated version of the prony brake this instrument employs electromagnetic interaction between a rotor and stator as a means of applying torque. The hysteresis brake proved well suited since it permits torque to be measured independent of speed and can be smoothly varied.

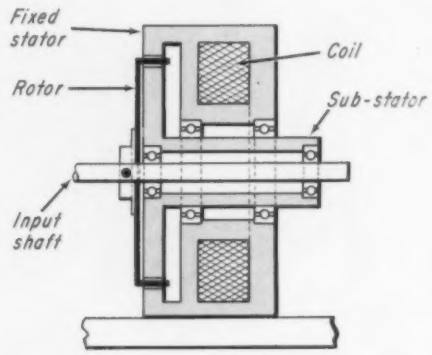
Accuracy is better than 1% over a range of 0.01 to 400 in.-oz. The 1200 series Running Torque Testers were designed by J Merl Director of Engineering and S Hejzlar, chief engineer of John Chatillon & Sons, NYC, NY. Increasing significance of appearance design suggested that the new model could benefit from the advice of industrial design consultant, Renwick, Thomson & Grove, N.Y.

The industrial designers proposed a single, continuous scale, almost as wide as the instrument itself. To further simplify readings, the rpm scale was centered below the torque scale, so that both can be read with a single glance. Readability is aided by the single contrasting color of the front panel surrounding the dial. Controls are grouped naturally on both sides of the test position, rather than all on one side as in the former model.



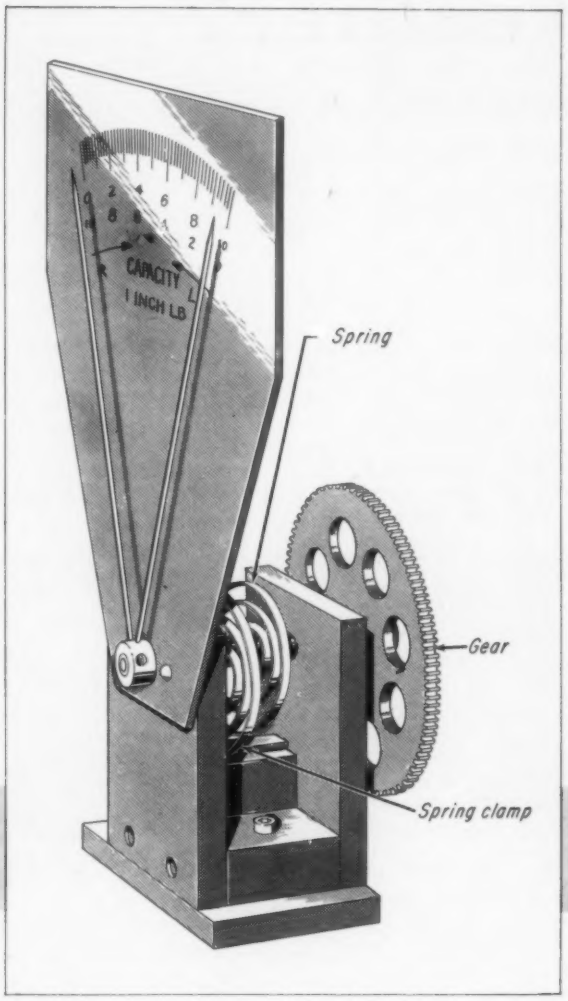
Torque source is connected to the input shaft of a hysteresis brake chosen because it can operate at high speeds, can absorb large amounts of energy, and the retarding torque is easily controlled by varying coil current. Magnetic flux generated by the energized coil couples cup-shaped rotor and stator.

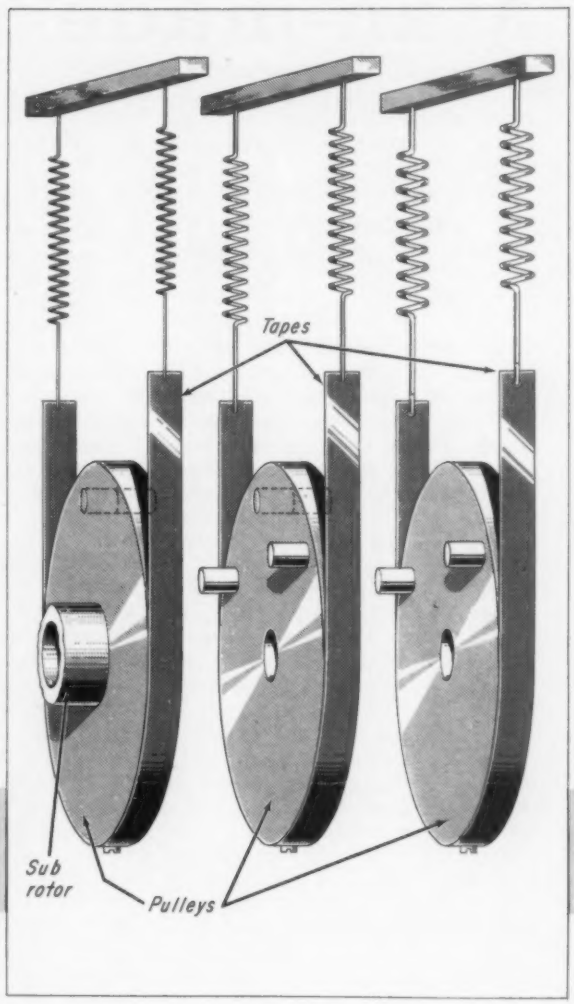
In the original design a spur gear on the stator winds up a fixed torsion spring and torque is indicated directly on a scale calibrated in in.-oz. The improved design incorporates a fixed stator and a movable substator to transmit force to the spring.



This provides an improved flux path and permits the use of a lighter rotor cup. The heavy stator is fixed to the base reducing inertia at the start of testing. In the original model the weight of the moving stator produced a shaft deflection that vibrated at the resonant frequency (approx. 12,000 rpm). It also created a flywheel effect that made instrument less sensitive to fluctuating motor characteristics. By reducing shaft load, smaller ball bearings could be used with lower internal friction. This improved high-speed and low-torque accuracy.

for hysteresis prony brake





Torsion-spring torque cells used in original design had limited capacity. This made it necessary to use three cells of different capacity to cover the operating range of the brake. Checking motors of unknown torque often required trial-and-error tests until the correct cell was selected.

The turret system in the redesign automatically shifts from one torque range to the next. Rotation of the sub-stator is transmitted to springs through steel tapes. Each end of the three tapes is connected to a temperature-compensated calibrated spring. Rotation of the sub-stator is restricted by the springs and the arc through which it travels is calibrated and indicated directly in in.-oz. Pulleys of the three spring sets are interconnected by a series of pins on facing sides. When the first pulley turns, ⅓ of its permissible range the projecting pins between the pulleys engage. This adds the load of second set of springs to the first set. When the second pulley turns ½ of its range its projecting pins engage the third pulley. Each spring is engaged smoothly as the sub rotor turns, producing a graduated cumulative reactive force which covers the complete operating range of the brake.

What progress toward
Man-made weather?

Tiros satellite photos are the most spectacular but not necessarily the most significant. A many-pronged research effort is now underway.

ROBERT E ABBOTT, senior associate editor

THE SPECTACULAR results of the Tiros meteorological satellites has touched off a new round of speculation that man will soon be able to modify weather—produce rain, thaw the north, and erase storms before they form. Chief of the US Weather Bureau, Dr F. W. Reichelderfer, summed up the matter of weather control this way: "This subject is still in the 'wide blue yonder', and at present nobody knows what the possibilities are. The scale of experimentation involved is of such magnitude that the questions can't be easily settled."

Knowing just what the effects of tampering with nature's weather phenomena will be is a key element in determining how far to go in rearranging the forces of nature. For example, if a hurricane or tornado is broken during its formation, it may move to a new area. Inducing rain in one area may produce droughts in others. Similarly, tampering with cold fronts may upset other climates.

40 million tons of snow

Weather bureau scientists estimate that during one year the energy equivalent of about 2 billion nominal nuclear bombs (20,000 tons of TNT equivalent) moves across latitude 40° in winds. They calculate that the energy in the winds over the entire globe at any one time is equal to about 7 million nuclear bombs.

The storm that hit New York City on Feb 4, 1961, dropped about 40 million tons of snow. To melt this snow would require the heat equivalent of 120 nuclear bombs.

For these reasons the US is currently spending around $100 million a year on weather research. The satellite program obviously takes the biggest chunk of the money. The weather bureau received some $6.9 million last year on researches of its own. This year it will spend $9 million. Another weather-modification program is being administered by the National Science Foundation as an integral part of a much broader program for atmospheric sciences. Topics under investigation include ocean-air interface problems, global circulation of the atmosphere, complex phenomena of the upper atmosphere such as the ionosphere, aurora and airflow, and solar-weather relations.

Last year, The Interdepartmental Committee for Atmospheric Sciences of the Federal Council for Science and Technology was established to keep the government fully advised of the expanding areas of atmospheric science and to encourage coordination among related programs. At the working level, nine agencies have formed an Interagency Conference on Weather Modification. Several joint research projects in weather modification have already been established between the Foundation and the Departments of Commerce, Agriculture, and Defense.

Current Research

Practical results from Foundation programs are already emerging even though the program is only in its second year. These include:

• **Silver-iodide particles** dropped on cumulus clouds which form over the Santa Catalina Mountains in Arizona. The results suggest that seeding produces larger thunderstorms, more lightning strokes, and precipitation from clouds that would not have precipitated naturally.

• **Artificially induced** space charge tried on cumulus clouds in Illinois. A stainless wire, suspended about 30 ft off the ground for 4 miles, was charged to a potential of 10 kilovolts. This charged wire ionized particles in the air passing by; the air was given a space charge concentration of about 1000 normal density. This checked a hypothesis which suggests that clouds are electrified as a result of the space charge in the air beneath them. It is believed that the electrical factors in clouds play a large role in the formation and release of heavy precipitation. The space charge did enter the cloud and further experimentation is needed to check precipitation changes. One finding: the four-mile-long wire was much too short and the clouds were not absorbing as much charge as desirable. New installation is using 30 miles of wire charged to a potential of 20 kilovolts strung in random arrangement over 60 sq miles of farm land.

• **Number and variation** of freezing nuclei in the air seem to make a difference. Increasing evidence has shown that the fluctuations or activity of natural freezing nuclei may be directly related to global patterns of heavy rainfall. Observations of freezing nuclei in the vicinity of Washington, DC, showed an unusually high count in air moving off the ocean while air from off the continent had lower concentrations. Other meteorologists believe that dust particles from outer space account for the great abundance of freezing nuclei. The question is thereby raised regarding the physical nature of at least some of the freezing nuclei in the

atmosphere. Future research must include upper-level sampling to determine if the results apply at the cloud and rain-forming levels in the atmosphere.

The US Weather Bureau has a program underway that eventually may reveal just what the effects of weather tampering will be. In the Bureau's General Research Laboratory, worldwide weather phenomena are being fed into a computer. Once the complete world weather picture is known, along with the reaction around the world to such elements as storms, solar flares, cold fronts, etc, alterations to these conditions will be fed to the computer to determine the new pattern on a simulated world weather map.

High hopes are riding on the computer program to lay a basis for ultimately deciding what long-range weather modifying should be attempted. Concurrent with determining the theoretical effects of such efforts, research is being advanced across a broad front to understand just what causes weather and how it can be altered to benefit mankind.

What's to come

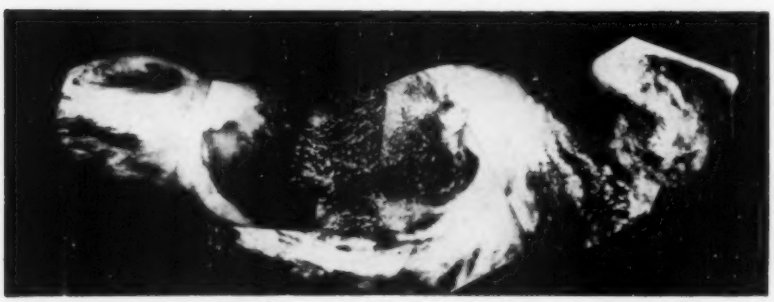
The most spectacular events in the study of the atmospheric sciences have been the success of the Tiros weather satellites. In addition to obtaining the usual instrument readings useful in meteorology, the major purpose was to photograph, in continuous sequence, large segments of the earth's surface.

Tiros photographs show clearly in broad detail, the types and patterns of such phenomena as cyclones and anticyclones. They verify weather predictions and give new insight into composition and movement of weather masses.

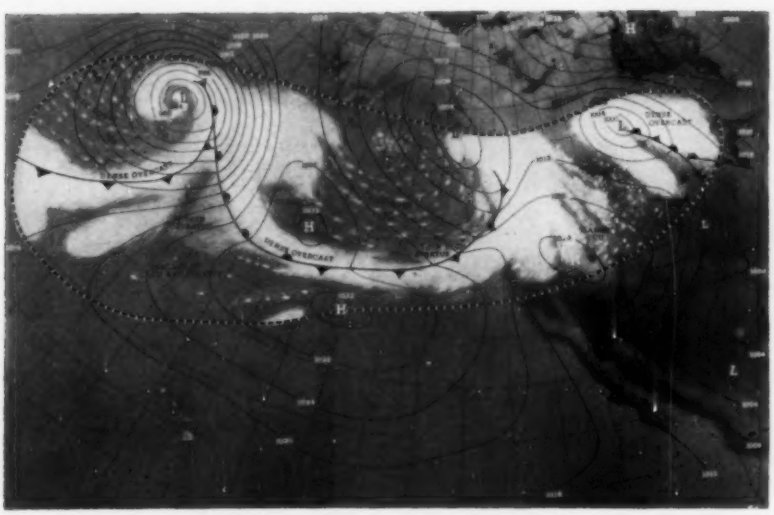
The most impressive feature is the discovery by Tiros I of well-developed cyclones covering much of the southwest US. Surface meteorological observations had given no hint of the storms. The collection of these data will make possible better weather predictions and serve as a guide to the study of weather modification.

Upon recommendations of the Committee on Meteorology of the National Academy of Sciences and after careful study by the National Science Foundation, a National Center for Atmospheric Research is to be headquartered on Table Mountain near Boulder, Colo. The mission of the Center is to study and explore the atmospheric envelope in which man lives. Its scientific program will be concerned primarily with an attempt to obtain a more profound understanding of the atmosphere. To accomplish its work the Center will be a:

- **Meeting place** for scientists from many fields—chemists, physicists, astronomers, computer experts, etc—with the hope of crossbreeding scientific ideas and thus give an imaginative approach to atmospheric problems.
- **Research planing** center for global-scale programs that cannot be attacked by individual university or research groups. It will not direct research but will stimulate planning of joint research operations in which each group will participate according to its interests and talents.
- **Research operations** center to synchronize and coordinate the complex operations of balloon flights, airplane flights, rocket launchings, etc.



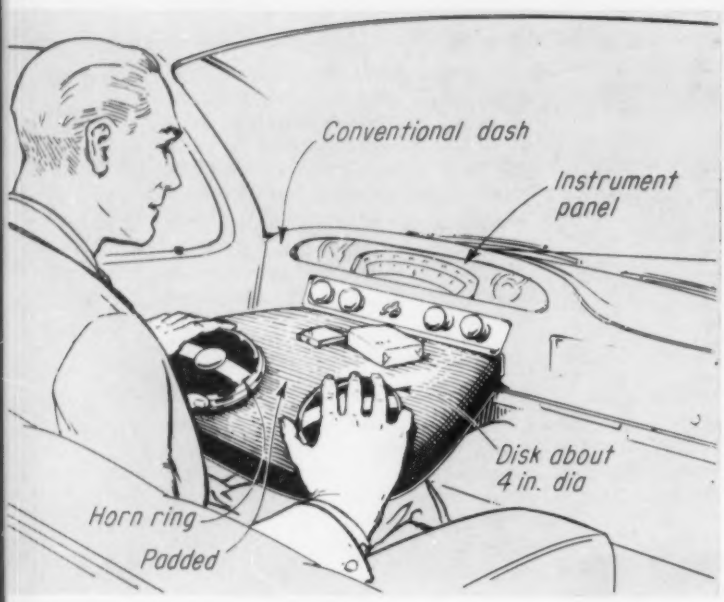
Photomosaic of Tiros pictures showing cloud cover . . .



. . . confirms and amplifies ground weather analysis

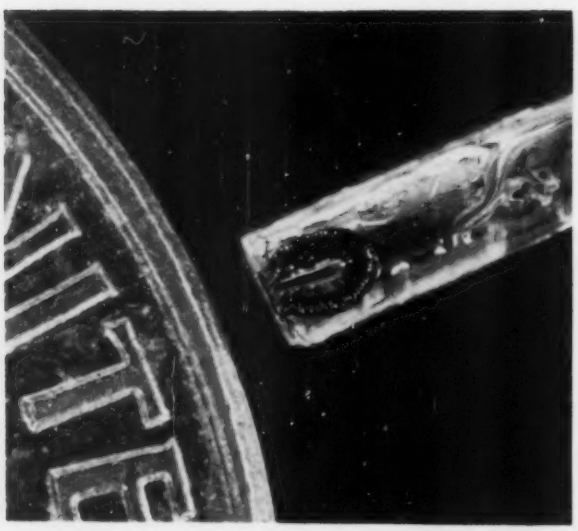
5000 MILES of the mid-Pacific and North American continent are covered by series of Tiros photographs taken on May 20, 1960. Such pictures when translated to map coordinates and superimposed on a conventional meteorological analysis can be used in conjunction with ground reports. Once pictures were taken, it was important to determine whether forecasting information could be extracted with sufficient speed to meet needs. Meteorological teams at data-acquisition stations analyzed the incoming data on the spot. Within six hours after receipt, resultant analyses, such as picture at left, were forwarded via facsimile transmission to the National Meteorological Center of the US Weather Bureau. These transmissions were then incorporated into the regular analyses of the weather bureau making long-range weather forecasting more exact.

PANORAMA

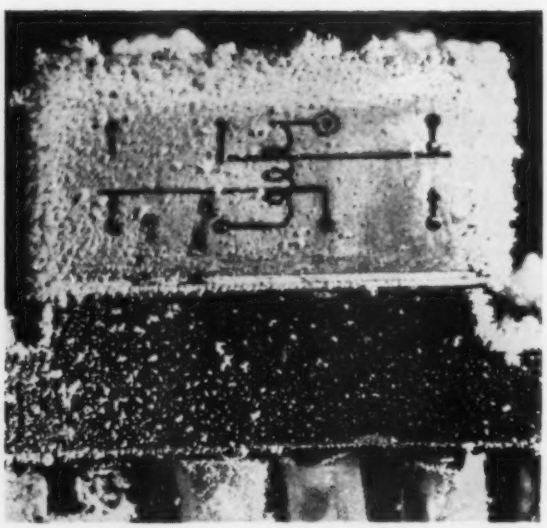


ARE KNOBS BETTER THAN A STEERING WHEEL?

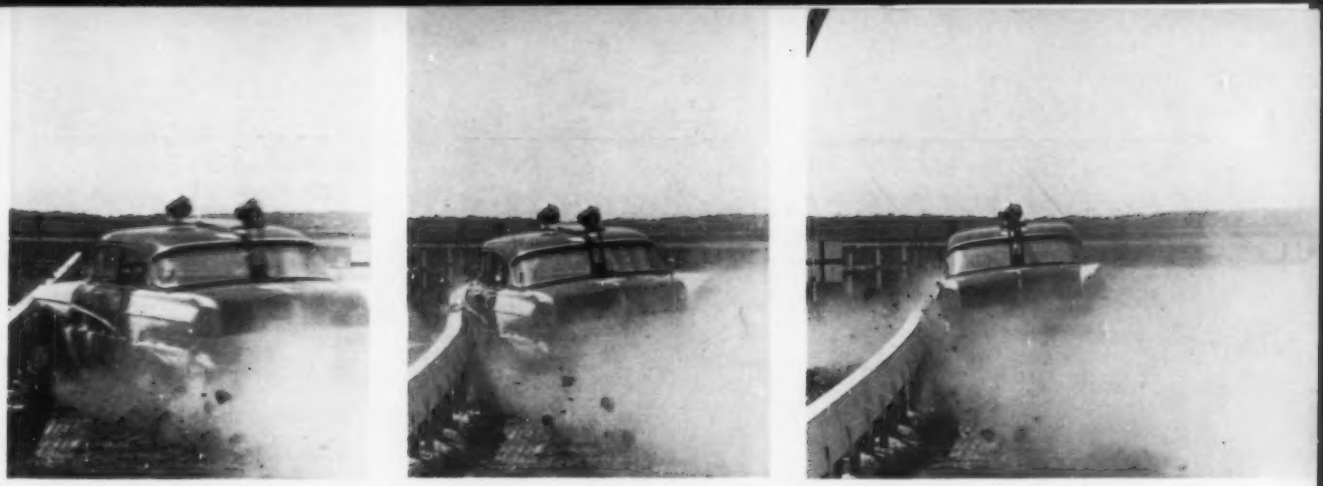
Two steering wheels may be better than one, at least GM's Saginaw Steering Gear Div and the Oldsmobile Div are willing to find out. Planned for the 1963 Olds Starfire as optional equipment, interconnected steering knobs are arranged on a Ouija-like board and mounted on the standard steering column. Knobs connect to the power steering unit through a chain-coupling mechanism that permits steering with either one or both knobs. GM personnel will not comment officially upon the device, or even admit its existence, however it has been learned that drivers of average skill, chosen at random, have become proficient within five minutes. The earlier "joystick" configuration, which combined steering, braking and accelerator pedal control, proved too difficult and there was doubt as to reactions in an emergency. No change is required in the specification of the hydraulic or geometric elements for this configuration. Estimates indicate that the unit will cost $77 to produce in limited quantity; retail cost of a factory installed control is tentatively pegged at $200, although design improvements may reduce this cost.



SMALLNESS IS A VIRTUE when it comes to inspecting metal parts, such as microminiature electronic components and mechanical assemblies. Search probe, developed by Battelle Memorial Institute, contains 200 turns of 0.000,-65-in. dia insulated wire wound around a 0.0008-in. dia iron core. Probe measures eddy and induction currents and, thus, pinpoints physical defects. Edge of dime gives idea of probe size.



COLD RELAY continues to function during simulated space flight in earth's shadow where temperature reaches –65 F. Leach Corp, Los Angeles, uses this method to insure near-perfect reliability of its units. Relay itself, identified by diagram, is no bigger than a dime, and is used to actuate power switching controls in Mercury capsules, where a single control switching malfunction could cause mission failure.



NEW CRASH BARRIER designs are tested at Cornell Aeronautical Laboratory, Buffalo, by running obsolete State Police cars into them at 60 mph. It's being done for the New York State Department of Public Works to get a detailed understanding of barriers subjected to car impact that can be applied for design purposes. Result should be a barrier that redirects a car along a path parallel to the barrier and gradually stops it. Engineers, traveling in a second car, operate the crash vehicle by radio control, sending it into the barrier at a predetermined speed and angle. Balls on car roof indicate center of gravity and angle at which auto strikes barrier.

WITH THE GREATEST OF EASE

He floats through the air on jets. Flyers will be instrumented to correlate operator in-flight control actions with resultant performance of the rocket belt. Textron's Bell Aerosystems Co and the Air Force Systems Command plan 40 flights by inexperienced operators to further system design improvements and to investigate the problems of maneuvering man in a space-flight environment. To date, all rocket belt free-flights have been made by Bell test engineer Harold M. Graham. The twin-jet rocket propulsion system was demonstrated at Fort Eustis, Va, (PE —June 19, p 21), to its military sponsor, the US Army Transportation Command. At that time, Graham flew some 360 ft over ground at an altitude of 3 to 4 ft. Range and altitude have been increased with additional flights. Sensors will record in-flight physiological information and performance data such as electrocardiogram, electromyogram, respiration rate, load imposed on body by rocket forces, stability and control measurements, accelerations in the roll, pitch, yaw axes at body center of gravity, and acceleration of upper body and lower limbs. Specks on photograph are dirt shaken loose from camera bellows when rocket belt operator hovered over supine photographer.

Engineering firms reduce

Foreign capital spending

US building boom in Europe dips as American firms modernize facilities there — start fewer new plants.

Investments overseas drop 4% in '62

Industry	Actual* 1960	Planned 1961	% Change 1961-62	Planned 1962
	(Millions of Dollars)			
Primary metals**	$101	$103	5%	$108
Machinery	132	173	3	178
Electrical machinery	104	134	—12	118
Transportation equipment (including autos)	336	544	—4	522
Other metalworking	42	40	10	44
Chemicals	237	275	5	289
Paper	78	72	—4	69
Rubber	68	73	10	80
Stone, clay & glass	37	44	10	48
Food & beverages	97	108	7	100
Misc manufacturing (including textiles)	105	100	—5	95
All manufacturing	1337	1666	—1	1651
Petroleum industry	1467	1760	—7	1637
Manufacturing & petroleum	2804	3426	—4	3288

**U.S. Department of Commerce.*
***Includes some mining companies.*

IN the decades since World War II, American industry has had a lasting influence abroad through construction of billions of dollars worth of plant and equipment. This flow of funds to build foreign installations may subside slightly next year, but will remain substantial. A McGraw-Hill Department of Economics survey finds that companies now plan to spend $3288 billion overseas in 1962—a 4% drop from the $3426 billion spent this year.

The anticipated decline in foreign investment is not expected everywhere. Next year US investment in the common market area (West Germany, France, Italy, the Netherlands, Belgium and Luxembourg) is expected to rise $23 million over this year and will account for ⅓ of total. This increase comes on top of a heavy transfusion of US capital to the common market this year: investment is now running 40% over 1960 as companies rush to get a base within this potentially large, but protected, market area.

The sharpest cuts in US industrial

American companies favor the European Common Market countries

Industry	Canada			Latin America			Common Market Countries			Rest of Europe		
	Actual 1960	Planned 1961	1962	Actual 1960	Planned 1961	1962	Actual 1960	Planned 1961	1962	Actual 1960	Planned 1961	1962
	(Millions of Dollars)											
Primary metals	$9	$13	$8	$51	$62	$81	$23	$18	$11	$14	$4	$4
Machinery	9	14	14	16	19	23	67	66	75	24	48	41
Electrical machinery	36	56	65	15	40	31	30	27	12	23	11	10
Transport equipment (including autos)	27	22	21	34	43	47	144	250	230	91	180	156
Other metalworking	3	3	3	5	5	6	16	16	19	7	12	11
Chemicals	74	41	35	33	77	69	47	66	67	45	33	43
Paper	72	65	59	2	0	3	0	0	3	3	6	3
Rubber	26	15	26	10	8	9	8	29	12	4	5	10
Stone, clay & glass	26	20	15	4	3	6	3	9	24	3	7	1
Food & beverages	35	36	30	16	10	3	14	5	18	26	52	41
Misc manufacturing (including textiles)	67	65	13	21	2	13	6	30	68	10	2	1
All manufacturing	384	350	289	207	269	291	358	516	539	250	360	321
Petroleum industry	360	370	329	340	475	409	151	187	200	194	214	229

construction will show up in Canada and European countries outside the common market. The deflection of investment from Canada is attributed primarily to that country's recession and recent efforts to discourage foreign capital. The decline of investments to non-ECM Europe, McGraw-Hill economists caution, may reverse itself if England joins the continental market.

Not all industries are slowing foreign expansion. The chemical industry will increase its overseas investment 5%, much of it in Europe—both in and out of the common market. The machinery industry will allocate 3% more to foreign plants, much of it within the ECM. On the other hand, the electrical machinery industry will cut investments 12%; and the transportation equipment industry will pare total expenditures $22 million, but will enlarge operations in Latin America by $4 million.

Modernization vs Expansion

Some 60% of all this overseas activity is to improve the competitive position of existing plants through modernization and replacement of old equipment. The remainder will be used to expand productive capacity. Emphasis on modernization is found especially in chemical, machinery and paper industries, while expansion predominates in the primary metals industries. Some 83% of its funds will go toward new capacity.

In Canada, modernization accounts for about 85% of total investment, in Europe and Latin America funds will be fairly evenly divided between modernization and expansion. Within the ECM about 52% of the money is headed for modernization projects, but is heavily concentrated in machinery, transportation equipment and rubber industries. All others are putting their money into new plants. The electrical machinery industry tops them all with 95%.

Additions to capacity appear consistent with growth potential and the high level of production these overseas plants have maintained. At the end of last year when US industry was operating at 77% of capacity, foreign branches were operating at 88%. In primary metals industries the discrepancies were even sharper: the iron and steel industry here limped along at 50% of capacity, while its foreign branches operated at 89%; and nonferrous metals industries here reported operations at 72% capacity, compared with 90% overseas. The paper industry reported 96% capacity for overseas branches at the end of last year and transportation equipment industry 94%. Only food and beverage manufacturers report more intensive operations here than abroad.

What effect on the US?

Last year, there was considerable alarm over our unfavorable balance of payments. The trouble was attributed in part to the steady export of US funds to build overseas branches. This flow will be counteracted to a small extent next year by the planned cut in total new investment. In addition US manufacturers report they will buy more of their equipment in the US—some $352 million worth. This amounts to about 21% of the total planned investment. Last year, equipment purchases here amounted to only $295 million—about 18% of total expenditures.

Somewhat harder to assess will be the effect of foreign operations on the exports of American companies. Manufacturing companies here view foreign export markets with optimism. Sales to foreign customers this year will aggregate an estimated $13.8 billion. Companies expect foreign sales to increase next year by about 3% to $14.3 billion.

This projected growth in exports is, however, well below the gain in sales projected for foreign subsidiaries, which over-all are expected to increase sales 10% next year. This year's sales will probably wind up about 6% over last. Especially sharp sales gains in 1962 are expected in chemicals (13%), machinery (12%), transportation equipment (12%), electrical machinery (11%), and stone, clay and glass (11%). (In contrast to most industry, manufacturers of transportation equipment here foresee a decline in overseas sales in 1962. It will probably amount to about 11%).

The decision of a company to build overseas, despite possible effects on exports, is based on a number of long-term considerations—but they all add up to increasing company profits. Not all profits are returned to the US each year—about 44% will be this year, and about 43% were in 1960. The amount returned depends upon the industry. Chemicals this year will siphon off some 74% of foreign earnings; transportation equipment, 48%; machinery 40% and electrical machinery, 19%, reports the survey.

over others

Other		
Actual 1960	Planned 1961	Planned 1962
(Millions of Dollars)		
$4	$6	$4
16	26	25
0	0	0
40	49	68
11	4	5
38	58	75
1	1	1
20	16	23
1	5	2
6	5	8
1	1	0
138	171	211
422	514	470

And rely on the US for new equipment

Industry	Actual 1960	Planned 1961	Planned 1962
	(Millions of Dollars)		
Primary metals	$86.9	$75.2	$84.2
Machinery	30.4	39.8	58.7
Electrical machinery	21.2	24.1	24.8
Transportation equipment (including autos)	30.2	38.1	57.4
Other metalworking	12.2	12.8	16.7
Chemicals	33.2	60.5	54.9
Paper	3.9	3.6	3.4
Rubber	4.1	4.4	4.8
Stone, clay & glass	5.9	5.3	11.0
Food & beverages	11.6	13.0	11.0
Misc manufacturing (including textiles)	36.8	18.0	24.7
All manufacturing	276.4	294.8	351.6
Petroleum industry	924.2	1144.0	1096.8

An exclusive interview

On defense R & D

Dr Harold Brown expresses his views on secrecy, private research, patents and team effort.

Dr Harold Brown, a 34-year old nuclear physicist, is director of defense research and engineering. He is in charge of a $4.8 billion program, which runs the gamut from basic research in the physical sciences to development of all types of military hardware. These programs represent close to half the nation's total R & D effort. Dr Brown graduated from Columbia at 18, was awarded his PhD at 22 for research in low-energy nuclear physics. He joined the Lawrence Radiation Laboratory, Livermore, Calif, in 1950, and when he succeeded Dr Herbert York in the Department of Defense, he was director of the laboratory. In recent years his research efforts have been in detection of nuclear explosions and other phases of arms control.

On prototypes. "It is not feasible to push major weapon systems into production, bypassing the prototype stage as this is where 'bugs' are worked out. It may be possible for some items such as small arms which have lower production costs. But, even here, a small increase in production costs could offset any saving of skipping the prototype stage."

On secrecy. "Dissemination of technical data among scientists engaged in classified work is becoming more complicated because more people are working on more projects. We're not successful enough in spreading research results among the 'need to know' group. It's simply a lack of time to find out what everyone is doing. Individual project leaders tend to share information among themselves primarily through technical meetings and personal contact. We lack classified journals, although improved indexing, such as is provided by the Armed Services Technical information Agency, is alleviating the situation, but this is only temporary."

On private research. "For items that have to be set up quickly and which require special technical skills not available in government laboratories, it is necessary and useful to set up private nonprofit research firms. We're a pluralistic society, and it is customary for us to do things more than one way. I don't know what the proper mix should be for research performed in government facilities, by industrial contractors, and nonprofit laboratories. Right now, the breakdown in roughly 25% in-house, 5% by nonprofit research organizations and universities, and 70% by industrial contractors. Also, rising industry salary patterns is making government recruitment of young scientists and engineers more difficult. Unless this is solved, it will be harder for us to do in-house research."

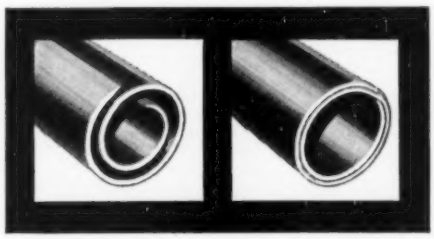
On patents. "As private companies are doing most of the military research and development, I forsee no significant problem in making the results of this work available to industry. In fact, much of the military work in missiles has shown up in the commercial trend toward miniaturization and the use of servomechanisms, transistors, and similar items. The policy of this department is to allow contractors title to patents generated by military-financed work, but require royalty-free use of the patents to government agencies. It is impossible to build a major electronic item today without cross-patenting and payment of royalties."

On military problems. "Variable geometry of aircraft for varying speed levels, boundary layer control associated with flight of advanced aircraft, and materials required for high-performance weapon systems are major headaches. Another, is the field of power conversion; to get energy from one place to another. The transportation of gasoline, for example, represents more than half our logistics problem. If we could use and store lower levels of energy, we would be much better off."

On teamwork. "It takes a team of researchers to work out the details on new military systems. Projects have become so complicated that an individual can't solve all the problems. But it takes an individual to recognize the problems and to come up with ideas to spark plug a group's effort. Today, the individual contribution is to push for achievement rather than complete technical development by himself."

Bundy can mass-fabricate practically anything

Almost any tubing problem can be solved by Bundy. Engineering and design specialists at Bundy are experienced in working out efficient fabrication methods and can often come up with design simplifications which reduce costs. Reason? Design and mass-fabrication of tubing components are our business . . . and have been for a long time. And you can make more different complex bends and shapes with Bundyweld® steel tubing. It meets Govt. Spec. MIL-T-3520, Type III; ASTM 254; and SAE specifications. Call, wire, or write: Bundy Tubing Company, Detroit 14, Michigan.



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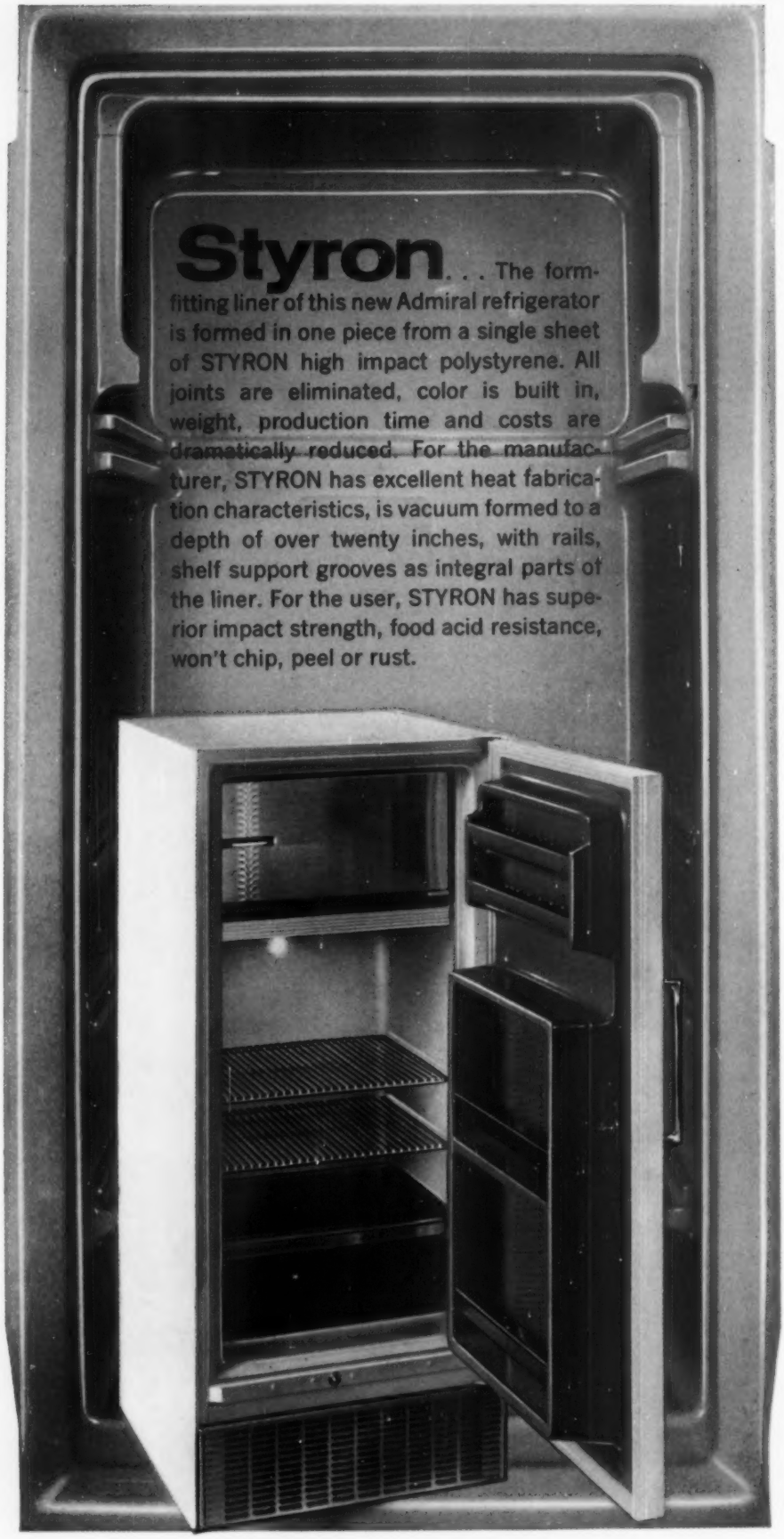
Bundyweld, double-walled from a single copper-plated steel strip, is metallurgically bonded through 360° of wall contact. It is lightweight, uniformly smooth and easily fabricated . . . has remarkably high bursting and fatigue strengths. Sizes up to ⅝" O.D.

BUNDY® TUBING COMPANY

DETROIT 14, MICH. • WINCHESTER, KY. • HOMETOWN, PA.

WORLD'S LARGEST PRODUCER OF SMALL-DIAMETER TUBING. AFFILIATED PLANTS IN AUSTRALIA, BRAZIL, ENGLAND, FRANCE, GERMANY, ITALY, JAPAN.


Styron. . . The form-fitting liner of this new Admiral refrigerator is formed in one piece from a single sheet of STYRON high impact polystyrene. All joints are eliminated, color is built in, weight, production time and costs are dramatically reduced. For the manufacturer, STYRON has excellent heat fabrication characteristics, is vacuum formed to a depth of over twenty inches, with rails, shelf support grooves as integral parts of the liner. For the user, STYRON has superior impact strength, food acid resistance, won't chip, peel or rust.

Styron... high impact Dow polystyrene

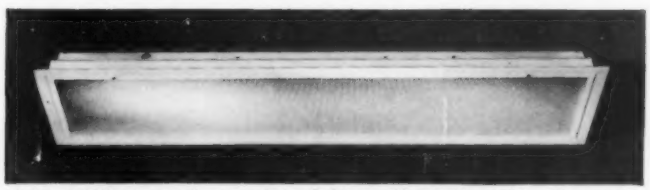
streamlines production in deep-draw, vacuum-forming operation for Admiral

The Styron® high impact polystyrene liner in Admiral Sales Corporation's new nine-cubic-foot apartment-size refrigerator cuts production time by 90% and up-grades quality and product appearance at the same time. This new concept in thermal forming offers designers and fabricators unlimited opportunities for deep-draw, one-piece components.

Using a new rotary vacuum-forming machine, and fifteen pounds of high-impact Styron 475B, Admiral deep-forms a one-piece refrigerator liner 46½" high x 23¾" wide x 20$^{12}/_{32}$" deep *in two minutes!* Contrast the half-hour total production time and the reduction in float quantities required in this operation with the five hours' total production time and twenty-two pounds of material required to fabricate the previously used liner.

The finished design: a smooth, food acid resistant liner with built-in color that won't crack, chip, or rust . . . with no joints . . . and with more efficient insulating qualities. Formed into the liner are the crisper rail, two shelf supports, grooves, a two-position freezer drawer slide rail, and four bosses for mounting the evaporator.

The unusual size of Admiral's one-piece vacuum-forming operation opens the door to deep-drawn designs of even larger and more complex shapes. May we add our experience to yours to help solve a design problem? Drop us a line in Midland, Attention: Plastics Sales Department 1721DZ9-18.



Light stabilized panel, extruded of Styron Verelite®, enables this K-S-H lighting fixture to provide a low brightness controlled light.

Transistor radio-phono combination by Bell Products is enclosed in case of Styron® for good impact strength and brilliant color styling.

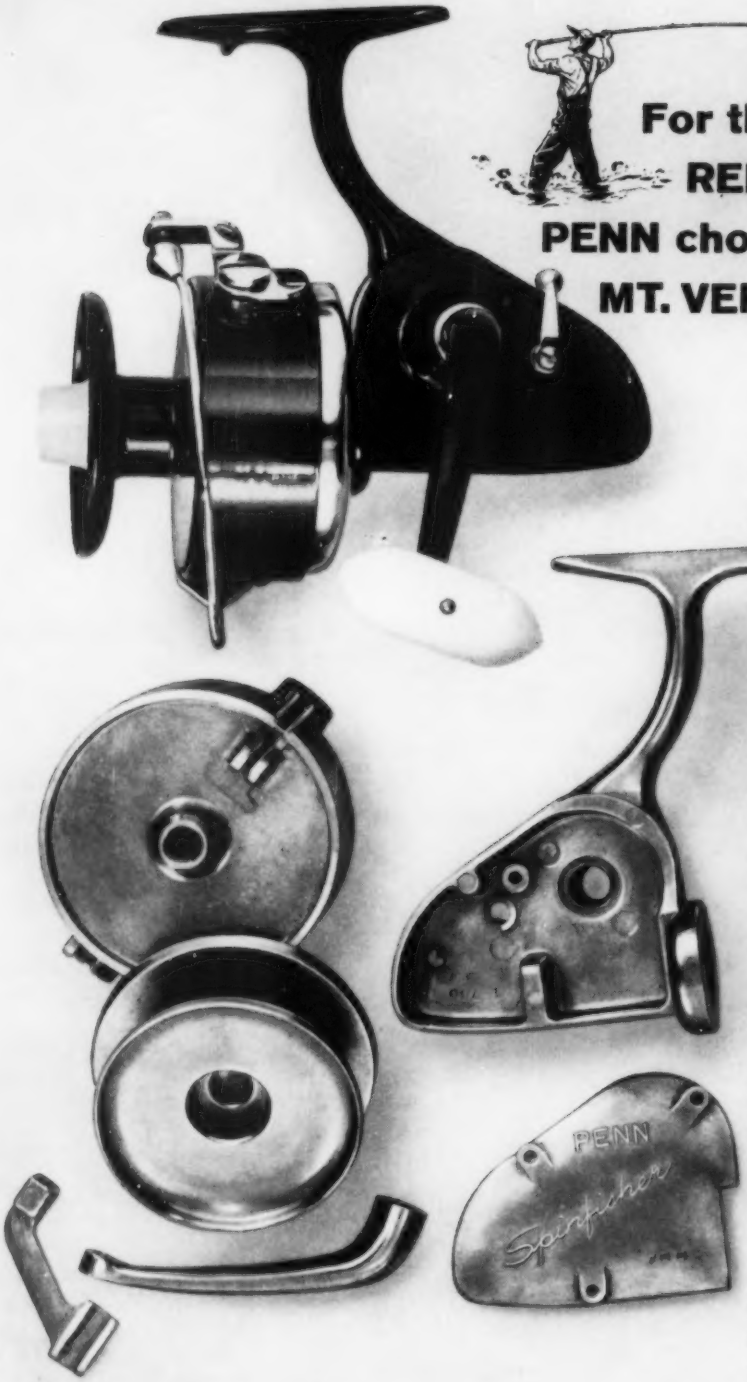
Wastebasket by Rubbermaid uses flexible, chip-resistant, easy-to-clean Dow medium density polyethylene. Letter tray of Styron.

THE DOW CHEMICAL COMPANY DOW Midland, Michigan

CIRCLE 115 ON READER SERVICE CARD 115

CASE HISTORIES FROM
MT. VERNON FILES

For their newest REEL of CHAMPIONS PENN chooses die castings– MT. VERNON die castings



Like other Penn "Reels of Champions," this new Penn Saltwater Spinfisher 700 will enjoy ready acceptance among both dealers and fishermen. It has 18 features—some exclusively Penn—which make it durable, corrosion resistant and simple to service.

3:8 to 1 gear ratio for fast retrieve—stainless steel gears and ball bearings—high-nickel stainless steel parts—automatic bail lock—250 yd. capacity spools—epoxy finished aluminum housings for strength—weight only 20½ ozs.—are some of its outstanding features.

Seven lightweight, aluminum castings (you get 2 one-piece spools complete with drag disk assembly) go into its construction. Quite a few castings—all precision, and several complex at that.

Aluminum die casting was the only feasible method for manufacturing such a champion—to hold down weight and cost and yet satisfy Penn's traditionally high standards of craftsmanship.

To Mt. Vernon went the honor of making the castings, because Mt. Vernon—like Penn—also enjoys a reputation for high standards of workmanship. At Mt. Vernon you gain through a fourfold service embracing: Designing • Die Making • Casting • Machining—all under one roof in 200,000 sq. ft. of space.

You, too, can set your standards as high as you wish—then confidently give your specifications to Mt. Vernon and relax. You'll get champion castings. A call to your nearest Mt. Vernon field salesman or our home office will get you prompt action.

MT. VERNON DIE CASTING CORPORATION

Stamford, Connecticut

FIELD SALESMEN–BALTIMORE, MD.: Mr. C. M. Gordan, 919 St. Paul St. • **BROOKLYN, N. Y.:** Mr. Robert V. Moore, 2317 Plumb 2nd St. • **MARIETTA, N. Y.:** Mr. Burt J. Meldrum, Olanco Road • **PITTSBURGH, PA.:** Mr. Andrew W. Anderson, 300 Pasadena Drive So. • **STAMFORD, CONN.:** Mr. Anker Anderson, Cascade Road • **VALLEY FORGE, PA.:** Mr. G. T. McMaster, P. O. Box 115

CIRCLE 117 ON READER SERVICE CARD→

Hamilton

DRAFTING EQUIPMENT

actually pays for itself

in increased efficiency

*and savings in floor space**

**Ask for our interesting Hamilton "INCREASED EFFICIENCY KIT." It will open your eyes to new drafting room economy!*

Pat. Pending

NEW Torsion AUTO-SHIFT Drafting Table

This new Hamilton drafting table combines truly imaginative engineering with an intimate knowledge of *today's* drafting procedures. It offers exclusive "freedom from fatigue" features, plus a new design that can provide space economies of up to 47%. Investigate the EXTRA/EFFICIENCY *only* Hamilton delivers!

EXCLUSIVE TORSION BAR MECHANISM
permits effortless fingertip board-tilt adjustment. Counterbalance compensates for weight added to board by drafting machines, lamps.

COMPLETE FILE-REFERENCE FLEXIBILITY
File-reference facilities may be installed for use at either side of table—to fit any layout, tailoring the *table* to the *draftsman*, *not* the draftsman to the table.

Hamilton Manufacturing Company, Two Rivers, Wisconsin

Hamilton brings

EXTRA / EFFICIENCY

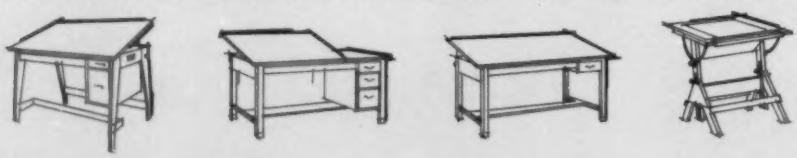
to your drafting facilities
through planned layout and
superior equipment performance

UNIT SYSTEM FILES
Maximum protection and storage capacity in minimum space. Each shallow drawer has an exclusive tracing lift mechanism so that every tracing becomes a top sheet, instantly accessible. Unit files stack in the arrangement that fits *your* needs and can be added to as your requirements grow.

NEW MODUCOR FILES
Smart, modern, practical—MODUCOR is the better way to file roll tracings in limited space, with a minimum investment. Three different tube sizes, with spring-activated doors, and label holders. Standard module construction permits integration with other Hamilton file units.

L-CONTOUR DRAFTING TABLE
A personalized work area unit for your top-level designer-engineer draftsmen. Completely flexible counterbalanced board combines with personal right- or left-hand reference and storage facilities to give you maximum efficiency and productivity.

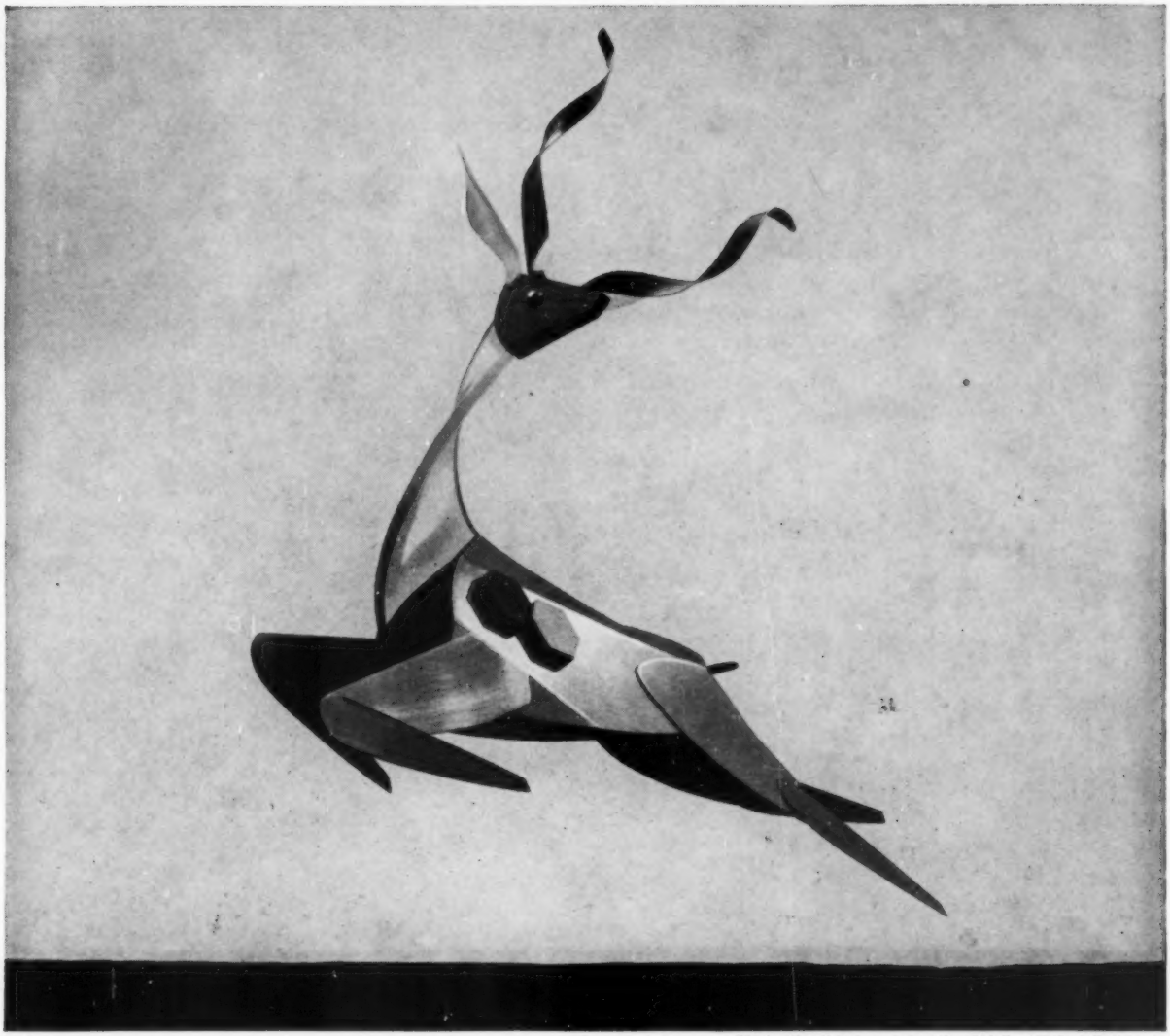
Other Hamilton *EXTRA EFFICIENCY* Drafting Equipment...



CL-100 Tables | Steelwood Drafting Tables | Four Post Drafting Tables | Tracing Tables

Hamilton
Manufacturing Company
Two Rivers, Wisconsin

Litho in U.S.A



Original sculpture created for 3M Co. by Guy Palazzola

Freedom

. . . New design concepts "take off" with 3M Brand Adhesive Products!

Want to escape design limitations imposed by old-fashioned fastening ways? Help yourself to new elbowroom with the modern, clean-lined, functional fastening you get with 3M Adhesives!

New simplicity! Using 3M Adhesives for assembly, you eliminate fasteners, nuts, bolts, rivets, staples. Fewer parts give you simpler construction that costs less, looks better. The making of necessarily complex shapes and castings, too, is simplified by 3M Adhesives; you break down the complex part into several simple sections, then adhesive-bond into one.

New material choices! With 3M Adhesives you bond practically any material to itself or to any other material. Metals (including magnets), woods, glass, ceramics, plastics, the whole works! Lighter gauge materials can be used because adhesives eliminate local stress concentrations, increase joint strength. The integrity of joined materials is unimpaired because holes (for fastening devices) and heat (for fusion) are eliminated.

New production savings! With the increasingly close liaison between industrial designer and production engineer, the many production savings inherent in adhesive bonding favor the design that employs 3M Adhesives. For a realistic appraisal of what 3M Adhesives can do to give you more design freedom, better production economics, call your nearest 3M Field Engineer or write to: AC&S Division, 3M Company, Dept. SBS-91, St. Paul 6, Minn.

"SCOTCH-WELD" is a Reg. T.M. of 3M Co. ©3M Co., 1961

What do you want to bond to what?

The 3M Gazelle is fabricated of these materials and bonded with 3M Adhesives, including SCOTCH-WELD® Brand Structural Adhesives:

1. Brass 2. Wood 3. Plastic 4. Ceramic 5. Copper 6. Stainless Steel 7. Aluminum.

ADHESIVES, COATINGS AND SEALERS DIVISION

MINNESOTA MINING AND MANUFACTURING COMPANY

. . . WHERE RESEARCH IS THE KEY TO TOMORROW

3M COMPANY

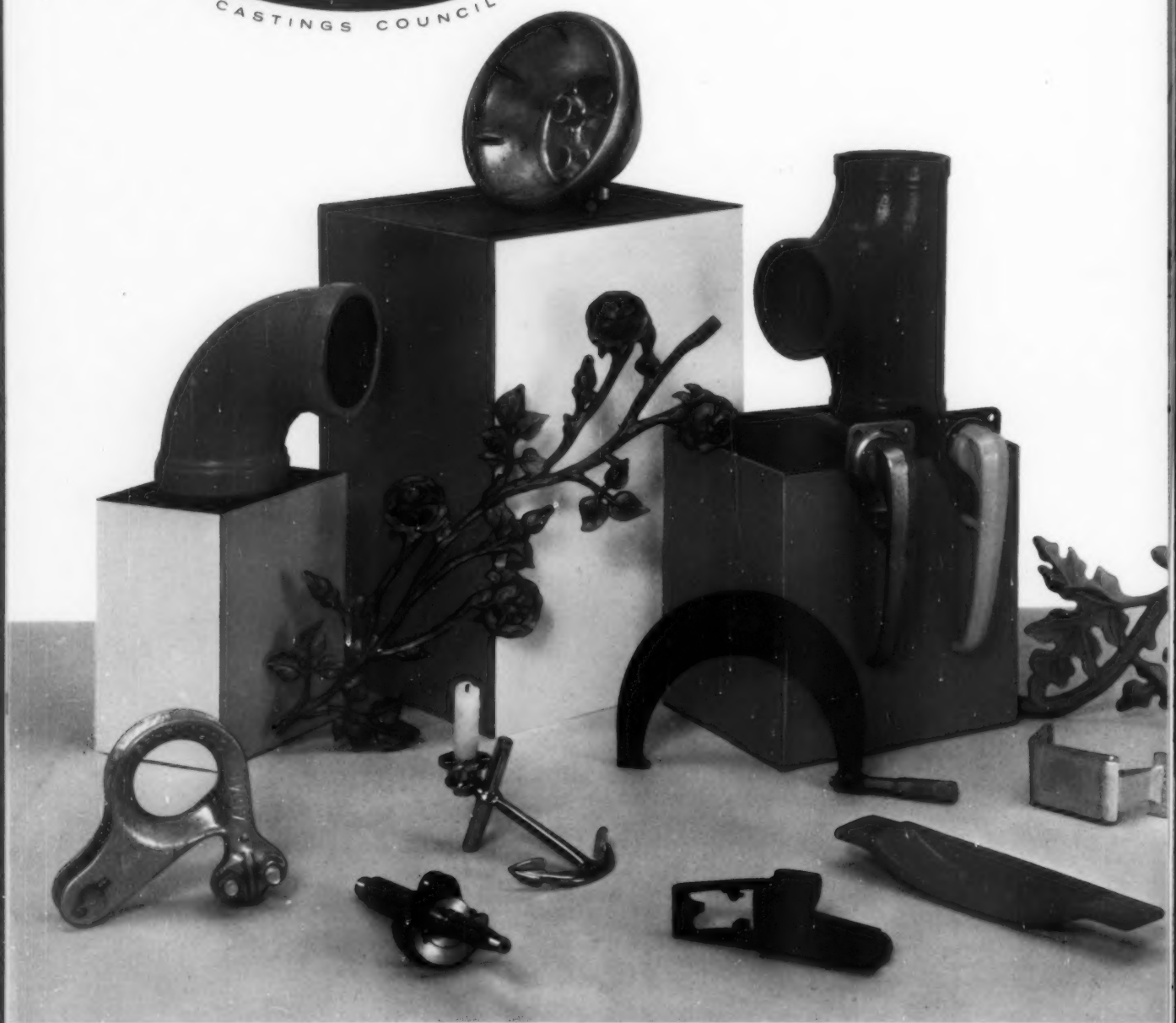
CIRCLE 119 ON READER SERVICE CARD

Now—Finishes Add Beauty to Tough Malleable Castings

Beautiful, protective finishes on tough Malleable iron castings will give your products a superior combination of appearance, ruggedness, and economy. Get complete information on this sales-getting combination from any of the progressive companies that display this symbol —

MEMBER
MALLEABLE
CASTINGS COUNCIL

New Ideas for your products are suggested in Data Unit No. 115, available free from any member of the Malleable Castings Council, or write to Malleable Castings Council, Union Commerce Building, Cleveland 14, Ohio.



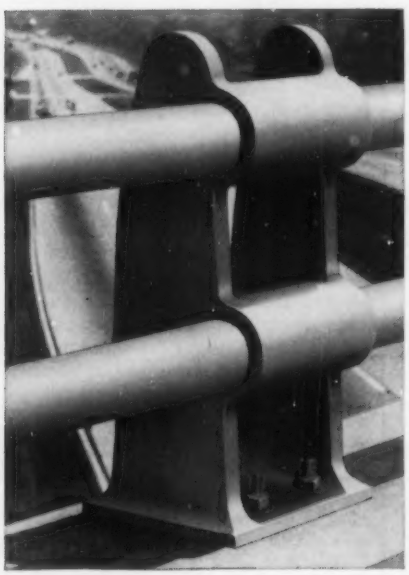
The castings shown have been painted, blued, chromium and cadmium plated, plastic coated, porcelain enameled, galvanized, and machine

When appearance and long service life are important to your products, Malleable castings offer many advantages. Painting, hot dip galvanizing, blueing, and electroplating have long been used with Malleable castings because of their economy, attractiveness, and resistance to a variety of destructive conditions.

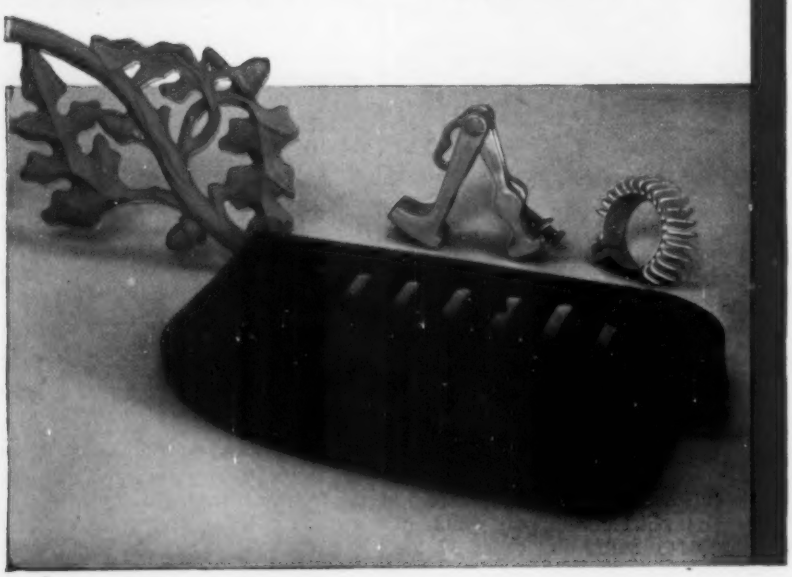
Several exciting new finishes appear very promising and are currently being tested by Malleable producers. Vinyl plastic in thin, contour-hugging films or thick, resilient coatings provide exceptional chemical resistance, and are available in a wide spectrum of strikingly beautiful colors.

Another attractive finish is porcelain enamel. In addition to smooth, gleaming surfaces in unlimited colors, it has excellent resistance to heat and chemicals.

The variety of finishes which can be successfully applied to Malleable gives designers outstanding opportunities to combine decorative and protective surfaces with the rugged dependability, economy, and versatility of Malleable castings. Call your Malleable supplier for information and quotations.



Bridge railing posts on the Connecticut Thruway are Malleable castings for three important reasons: (1) strong, ductile Malleable offers far greater resistance to fracture upon collision than other materials tried, (2) Malleable is easily galvanized for additional salt air corrosion resistance, and (3) with thousands of these posts in use, Malleable's economy produced real savings.



For Quality and Economy Use

MALLEABLE

For Service Contact...

CONNECTICUT
Connecticut Mall. Castings Co., New Haven 6
Alloy Foundries Division, The Eastern Co., Naugatuck

ILLINOIS
Central Fdry. Div., Gen. Motors, Danville
Chicago Malleable Castings Co., Chicago 43
Moline Iron Works, Moline
Moline Malleable Iron Co., St. Charles
National Castings Co., Cicero 50
Peoria Malleable Castings Co., Peoria 1
Wagner Castings Company, Decatur

INDIANA
Albion Malleable Iron Company, Muncie Division, Muncie
Link-Belt Company, Indianapolis 6
National Castings Co., Indianapolis 22

IOWA
Iowa Malleable Iron Co., Fairfield

MASSACHUSETTS
Belcher Malleable Iron Co., Easton

MICHIGAN
Albion Malleable Iron Co., Albion
Auto Specialties Mfg. Co., Saint Joseph
Cadillac Malleable Iron Co., Cadillac
Central Fdry. Div., Gen. Motors, Saginaw

MINNESOTA
Northern Malleable Iron Co., St. Paul 6

MISSISSIPPI
Mississippi Malleable Iron Co., Meridian

NEW HAMPSHIRE
Laconia Malleable Iron Co., Laconia

NEW YORK
Acme Steel & Mall. Iron Works, Buffalo 7
Frazer & Jones Company Division The Eastern Co., Solvay
Oriskany Malleable Iron Co., Inc., Oriskany
Westmoreland Mall. Iron Co., Westmoreland

OHIO
American Malleable Castings Co., Marion
Central Fdry. Div., Gen. Motors, Defiance
Dayton Mall. Iron Co., Ironton Div., Ironton
Dayton Mall. Iron Co., Ohio Mall. Div., Columbus 16
National Castings Co., Cleveland 6

PENNSYLVANIA
Buck Iron Company, Inc., Philadelphia 22
Erie Malleable Iron Co., Erie
Lancaster Malleable Castings Co., Lancaster
Lehigh Foundries Company, Easton
Meadville Malleable Iron Co., Meadville
Pennsylvania Malleable Iron Corp., Lancaster

TEXAS
Texas Foundries, Inc., Lufkin

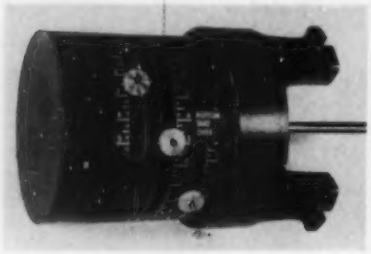
WEST VIRGINIA
West Virginia Mall. Iron Co., Point Pleasant

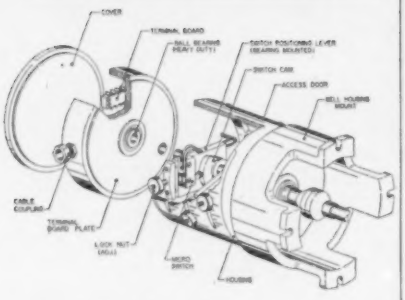
WISCONSIN
Belle City Malleable Iron Co., Racine
Chain Belt Company, Milwaukee 1
Federal Malleable Company, Inc., West Allis 14
Kirsh Foundry Inc., Beaver Dam
Lakeside Malleable Castings Co., Racine
Milwaukee Malleable & Grey Iron Works, Milwaukee 46

These companies are members of the Malleable Castings Council

CIRCLE 121 ON READER SERVICE CARD 121

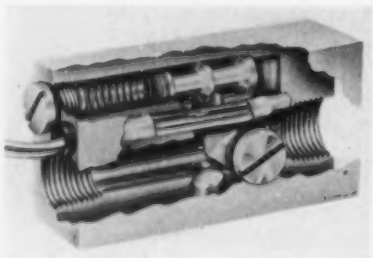
NEW COMPONENTS





Rotary cam switch . . .
available with one to six cams, can be adjusted quickly from outside while cams are stationary or in motion. Adjustment range is up to 180° for each stage. Designed for commercial equipment where a synchronous pulse or series of pulses is required and where rapid adjustment is desired while switch is in motion. Suitable for speeds up to 2000 rpm and torque of approx 3 oz-in. Either clockwise or counter-clockwise rotation is furnished. Upon reversal, switch will not trip (optional feature). Has heavy-duty, ball bearing construction throughout and is rated 15 amp up to 480 v ac. Cams are supplied with any degree of dwell. Prices start at $150 with delivery in 10 days to 2 wk. **General Automation Corp, 121 Centre Ave, Secaucus, NJ.**

Circle 300 on Reader Service Card

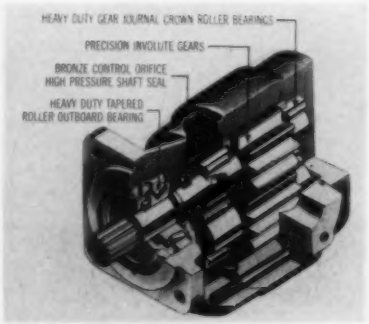


Flow switch . . .
is field-adjustable to detect variations in flow rate of fluids or gases for a positive indication. Operates a remotely located warning light or other visual or audio indicator. Used in conjunction with a flowmeter, unit can be adjusted to give warning or control at a predetermined flow. Displacement of magnet-equipped shuttle by fluid or gas actuates hermetically sealed switch contacts. Externally adjustable, vane-type, bypass valve provides a continuous range of actuation from 0.1 to 10 gpm for fluids and from 0.5 to 30 scfm for gases. Furnished with ½-in. NPT inline ports which can be installed in any straight line of piping. Contains no diaphragms or linkages to wear. Prices are $65 for brass housing, $95 for steel housing with quantity discounts. Delivery in 30 days. **Gems Co Inc, Sheppard Lane, Farmington, Conn.**

Circle 301 on Reader Service Card

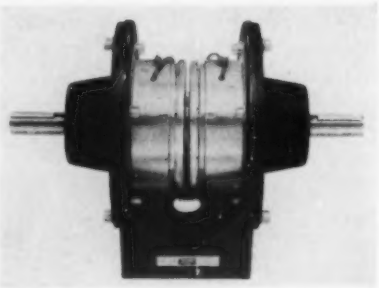
Suspension type meter . . .
uses a short, very thin, narrow band kept tightly suspended on special spring terminals to support coil and its moving counter parts. Contains no pivots, jewels, hairsprings or rolling friction. Conical shape spring anchors are said to provide max resiliency for the taut suspension wire when a shock or jar reaches it from any direction. Instrument is available in 2½-, 3½-, 4½-, 6-, 7- and 8-in. case sizes. **Triplett Electrical Instrument Co, Bluffton, Ohio.**

Circle 302 on Reader Service Card


HEAVY DUTY GEAR JOURNAL CROWN ROLLER BEARINGS
PRECISION INVOLUTE GEARS
BRONZE CONTROL ORIFICE HIGH PRESSURE SHAFT SEAL
HEAVY DUTY TAPERED ROLLER OUTBOARD BEARING

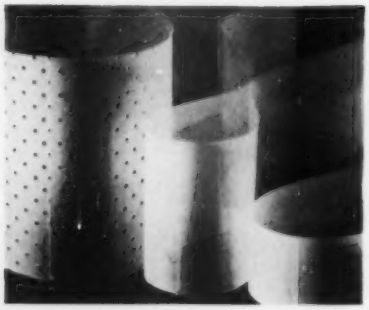
2500-psi gear pump . . .
is available in three series with output delivery ranging from 7 to 97 gpm at 1800 rpm. Redesign of drive's tooth contour and driven gears is said to permit pump to operate with greater discharge per in. of gear width than was possible in previous models. Also contains new extra-duty crown roller bearing, which reportedly keeps pump internally aligned and prolongs pump life. Series 25 with a delivery range of 7 to 35 gpm is available with gear widths of ½, 1, 1½ and 2 in.; series 37 has delivery range of 11 to 56 gpm and gear widths from ½ through 2½ in.; and series 65 has delivery range of 45 to 97 gpm and gear widths from 1½ through 3¼ in. All three series are recommended for continuous duty operation at pressure up to 2500 psi at 1800 rpm. **Commercial Shearing & Stamping Co, Youngstown, Ohio.**

Circle 303 on Reader Service Card



Clutch-brake package . . .
for fractional-hp duty cycle applicatons, is a pre-aligned unit that bolts in place with no engineering or machining. Up to several hundred machine cycles a min. can be accomplished using unit with continuously running electric motor or other power input. Consists of a standard stationary-field clutch and replaceable-face brake in an open package for max heat dissipation. Available in three sizes rated 10, 60 and 240 lb-in. static torque for max shaft speeds of 10,000, 7500 and 5000 rpm, respectively. From stock at $132, $174 and $236 each. **Warner Electric Brake & Clutch Co, Beloit, Wis.**

Circle 304 on Reader Service Card



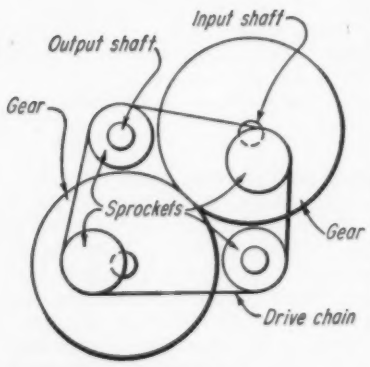
Endless polyester belts . . .
tapes and loops are spliced without heat or adhesives with joints 90 to 100% as strong as original material. Made possible by ultrasonic splicing method in which overlapped ends are traversed by an ultrasonic vibrat-

ing horn. Horn transmits energy through polyester in such a way that surfaces to be joined are brought within atomic distances of each other and adhere with mild clamping pressure. Extends applications which formerly were limited by difficulties with heat splices that disturbed polyester orientation. Available are Mylar belts in any length, widths from ¼ in. or less to 60 in. and thicknesses from 1 to 10 mils or more; and Cronar belts with standard perforations, widths from 16 to 70 mm and thicknesses of 4 or 7.5 mils. Overlap is a max of 0.050 in. ±0.001 in. and thickness of joint does not exceed mil thickness of material by more than 10% (thickness variation can be held to ±1% on request). **International Ultrasonics Inc, 331 Centennial Ave, Cranford, NJ.**

Circle 305 on Reader Service Card

Waterproof limit switch . . .
is low-cost, snap-action unit capable of underwater operation without leakage. Has min life capacity of 1 million cycles and has been actuated 200,000 times with full overtravel under 1-in. head of water without leaking. Plunger, made of Delrin, is sealed in a special neoprene boot. Outer case is nylon. Available with wire leads potted in epoxy resin or spade terminals. Said to be priced considerably less than conventional sealed switches. **Controls Co of America, 9555 Soreng Ave, Schiller Park, Ill.**

Circle 306 on Reader Service Card



Intermittent motion drive . . .
available in either 40 or 140° dwell, provides smooth acceleration-deceleration motion on packaging equipment, indexing tables, metalworking machines, punch presses, etc. Smoothness of operation results from system of chain-driven gears which have sprockets mounted eccentrically on them so that acceleration and deceleration takes place gradually (see sketch). Permits continuous motion input to "stop" or "dwell" momentarily on output side. Also can eliminate shock on single revolution clutches because of its output shaft which makes one complete revolution for each complete revolution of input shaft. Both models have max working torque of 50 ft-lb and tolerate momentary shock loads up to 50% of working load. Both are square shape, measuring 9¾ in. sq, with small model having a thickness of 4¾ in. and large model, a 7⅛-in. thickness. Shafts protrude approx 1¾ in. beyond drive case. Small model is priced at $420; large model, $640. **Remmele Engineering Inc, 515 University Ave, St Paul, Minn.**

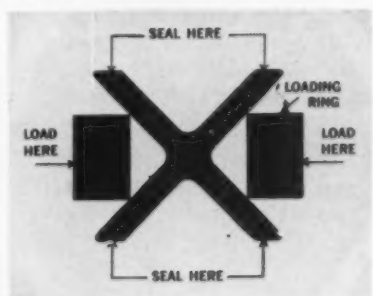
Circle 307 on Reader Service Card

Inherent motor protectors . . .
installed in end windings or stator slots, can be applied safely in integral-hp motors through 200 hp, 600-v max. Even larger motors can be protected with these devices with special design considerations. Also can be used as bearing temperature protectors in pump and motor applications. On 3-phase motors, one unit is used for each phase. Additional units are recommended for part-winding motors. Units measure motor temperature by intimate contact with windings; anticipate temperature of winding on fast rate of rise (trip point is an inverse-function of rate of rise); protect regardless of ambient temperatures external to motor; eliminate nuisance tripping; and use motor service factor to the maximum. Snap-action contacts allow control devices to be operated directly, eliminating need for an auxiliary relay in most applications. Nominal trip points vary with form used from 75 to 170 C. Trip points are available in 5 C increments, at ultimate trip temperature with slow rate of rise. Trip point tolerances are ±5% of nominal trip point. Bimetal element, based on a fast expanding tube, operates the snap-acting contacts. **General Electric Co, Schenectady 5, NY.**

Circle 308 on Reader Service Card

Low pressure filter assemblies . . .
rated 150 psi at 100 F, are available with pore size ratings from 2 to 100 microns, flow ranges of 30, 60 and 90 gpm and with three element materials, including woven wire cloth, sintered woven wire cloth and resin-impregnated cellulose fiber sheet. Materials are pleated for max filtration and dirt holding capacity. All three sizes use same element, but may vary with one to three elements depending on flow rate. In sizes using two and three elements, elements are stacked concentrically in assemblies with correspondingly longer housings. **Bendix Corp, 434 W 12 Mile Rd, Madison Heights, Mich.**

Circle 309 on Reader Service Card



Circular metal seal . . .
with cruciform profile, remains effective at temperatures from −400 to 1500 F and at pressures from spatial vacuum to 6000 psi. Originally developed for hydraulic actuators on aircraft, seal is said to be suitable where rubber O-rings may fail in: hot gas servos, cartridge actuator devices and for any long-time storage requirement. Cannot be set backwards or upside down because of its uniform symmetry. Available in static and dynamic styles, with diameter sizes

continued, page 124

TIMING USES

PHYSIO-THERAPY MACHINES

PAINT MIXERS

FANS

WASHING MACHINES

AIR CONDITIONERS

LABORATORY CENTRIFUGES

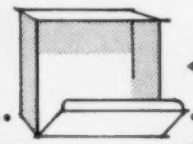
BATTERY CHARGES

STERILIZERS

PARACHUTE REEFING LINE CUTTERS

PHOTO-COPY EQUIPMENT

FOR *over* 3000 VARIATIONS OF ... "MARK-TIME"



Reserved For Your Timing Problem

TIMING DEVICES

4 GOOD REASONS

RELIABILITY

Spring power eliminates dependence on electrical power source. The mainspring is made from a new, super-tough special steel alloy, which virtually eliminates failure, and is UNBREAKABLE.

VERSATILITY

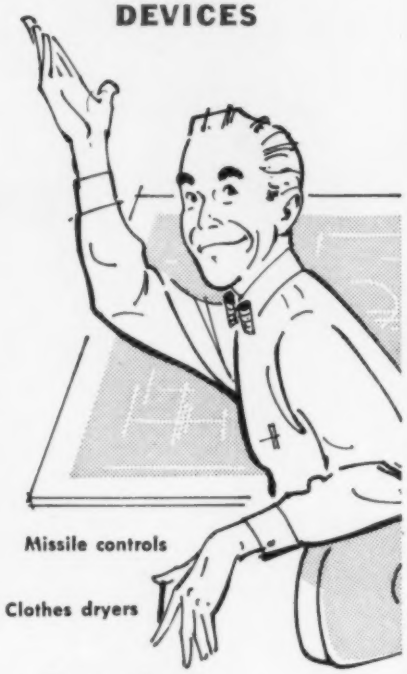
Our timing devices are designed to ring bells, flash lights, turn valves, pull release pins, cut cords, open containers, and start, stop or operate electrical or mechanical equipment.

LOW COST

Many Timers use basically the same parts and components. Thus, slight variations can be produced at quite attractive prices.

SHORT RUNS

A speciality. R & D work welcome.



Missile controls

Clothes dryers

X ray equipment

Lighting equipment

Space heaters

Bulk milk coolers

. . . and many others

Write for your copy of our new Catalog.

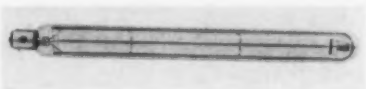
M. H. RHODES, Inc.
Hartford 6, Connecticut

In Canada M. H. Rhodes (Canada) Ltd.
Ottawa 5, Ontario

MARK-TIME ®

from ⅜ to nearly 12 in. Static seal is a one-piece metal circle, machined to form four structural legs of the "X". Inserted between face plates, legs exert four-point loading. Since center of X shape cannot rotate, possibility of tilt or twist is eliminated. Dynamic seal, which has same four-point stability, has adjustable loading rings added to its lateral sides. During movement, such as impulses or reversal in a cycling process, rings produce reflex action on legs. This prevents position shift and insures continual sealing contact. Aluminum alloys, stainless steels and Inconel-X are base seal metals, with several platings available to accommodate specific needs. **E B Wiggins Oil Tool Co, 3424 E Olympic Blvd, Los Angeles 23.**

Circle 310 on Reader Service Card

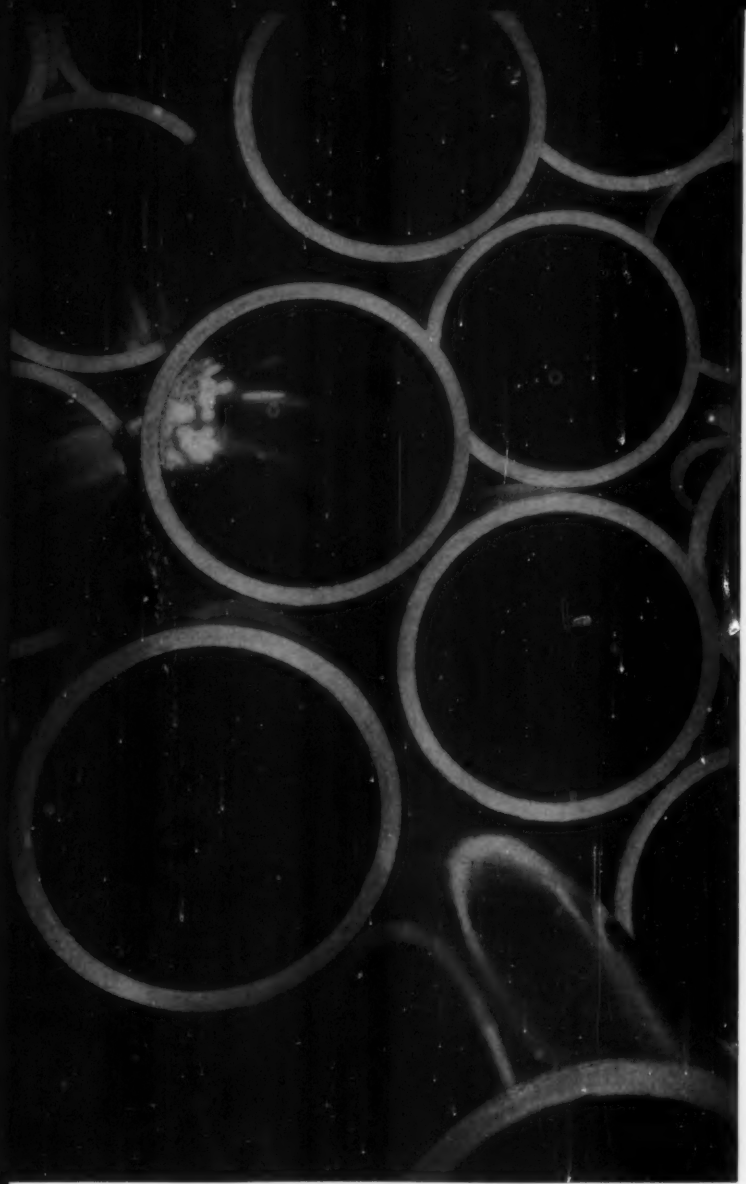


Straight filament lamp . . . uses ribbon filament instead of conventional coiled or round wire type. This is said to substantially increase directional candlepower with no increase in wattage. Filament is spring tensioned and remains straight during operation. Lamp, suitable for punched card readout devices, can be made in lengths up to 7 in. or more, which permits punched cards to be read in a vertical position for increased equipment capacity. **Chicago Miniature Lamp Works, Dept PE-1, 1500 N Ogden Ave, Chicago 10.**

Circle 311 on Reader Service Card

Dual purpose transducer . . . either detects or excites vibrations without contacting object to be tested. Useful in cases where object to be measured has so small a mass that any contact with an indicating instrument would influence vibration. Object to be measured, or vibrated, need not be magnetically conductive. By affixing a thin disk of silicon steel to object, it is rendered effective for study by pickup. Unit measures both relative and absolute vibrations, transforming vibrations into electrical voltages whose magnitude is proportional to velocity. To excite vibrations, pickup is connected to output of an audio frequency oscillator, inducing resonant vibrations in reeds, membranes, diaphragms, light sheet metal, etc. Unit consists of a cylindrical,

continued, page 126



This mark tells you a product is made of modern, dependable Steel.

Smooth . . . inside, outside . . . and accurate, too!

For a very fundamental reason, more and more Engineers, Designers and Purchasing Agents are specifying USS National Electric Resistance Welded Steel Mechanical Tubing—it saves money.

Dimensional accuracy and closely controlled mechanical properties insure consistency—consistently low machining losses, uniform strength, low fabrication costs and high torsion resistance—and the tubing is smooth inside and outside.

Whether your tubing application requires the dependability for a load-carrying member or the surface smoothness quality for a hydraulic cylinder, USS National Electric Welded Mechanical Tubing must be your first consideration.

USS National Electric Welded Mechanical Steel Tubing is available in a wide range of cold drawn or hot rolled sizes from as small as ⅜″ x .028″ to as large as 5½″ x .250″. Your National Tube Distributors throughout the country will gladly show you how tubing can reduce your costs. See your USS National Tube Distributor.

USS and National are registered trademarks

National Tube Division of United States Steel

USS

Columbia-Geneva Steel Division, San Francisco, Pacific Coast Distributors
United States Steel Supply Division
United States Steel Export Company, New York

CIRCLE 125 ON READER SERVICE CARD

WHEN SPACE IS LIMITED AND WEIGHT IS A FACTOR

A NEW MAC LEAN-FOGG LOCKING FASTENER

WHIZ-LOCK FLANGETTE

SMALLER !

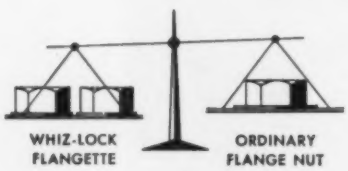
The new M-F Flangette Lock Nut is much smaller than ordinary flange nuts, yet is structurally strong, locks dependably, simplifies assembly.

No. 10 FLANGETTE

No. 10 FLANGE NUT

LIGHTER !

Keep weight down with the M-F Flangette. The tiny flange strengthens the entire nut . . . permits lighter body. Weight: considerably less than the conventional flange nut of equivalent size.

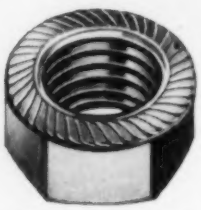


WHIZ-LOCK FLANGETTE

ORDINARY FLANGE NUT

SAFE, SURE LOCK !

The "Flangette" utilizes the patented MacLean-Fogg Whiz-Lock principle. Spins on—locks to the surface on which it bears. Easiest of all lock nuts to apply. Withstands shock and vibration.



WHIZ-LOCK FLANGETTE UTILIZES M-F PATENTED WHIZ-LOCK LOCKING PRINCIPLE

AVAILABLE IN 4 SIZES: No. 6, No. 8, No. 10, 1/4"

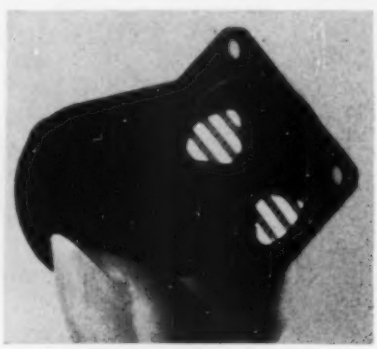
SAMPLES ON REQUEST

MAC LEAN-FOGG M-F LOCK NUTS

MacLean-Fogg Lock Nut Company
5535 N. WOLCOTT AVENUE
CHICAGO 40, ILLINOIS

splashproof metal housing, containing a permanent magnet with a coil. Iron parts touching detector do not affect its magnetic power or sensitivity. If a magnetically conductive object is brought near the "open" magnet pole, magnetic flux through the magnet and coil will change, inducing an alternating voltage in the coil, analogous to velocity of the vibration. Unit has max sensitivity of 80 mv/cm/sec; frequency response of up to 120,000 cpm with a 15% dropoff at 60,000 cpm. Measures ⅞ in. dia and 2 in. long. Furnished with 16-ft-long connecting cable and 10 silicon steel disks at $145. Delivery in 2 to 3 wk. **Korfund Co Inc, Acoustics & Instruments Div, Cantiague Rd, Westbury, LI, NY.**

Circle 312 on Reader Service Card

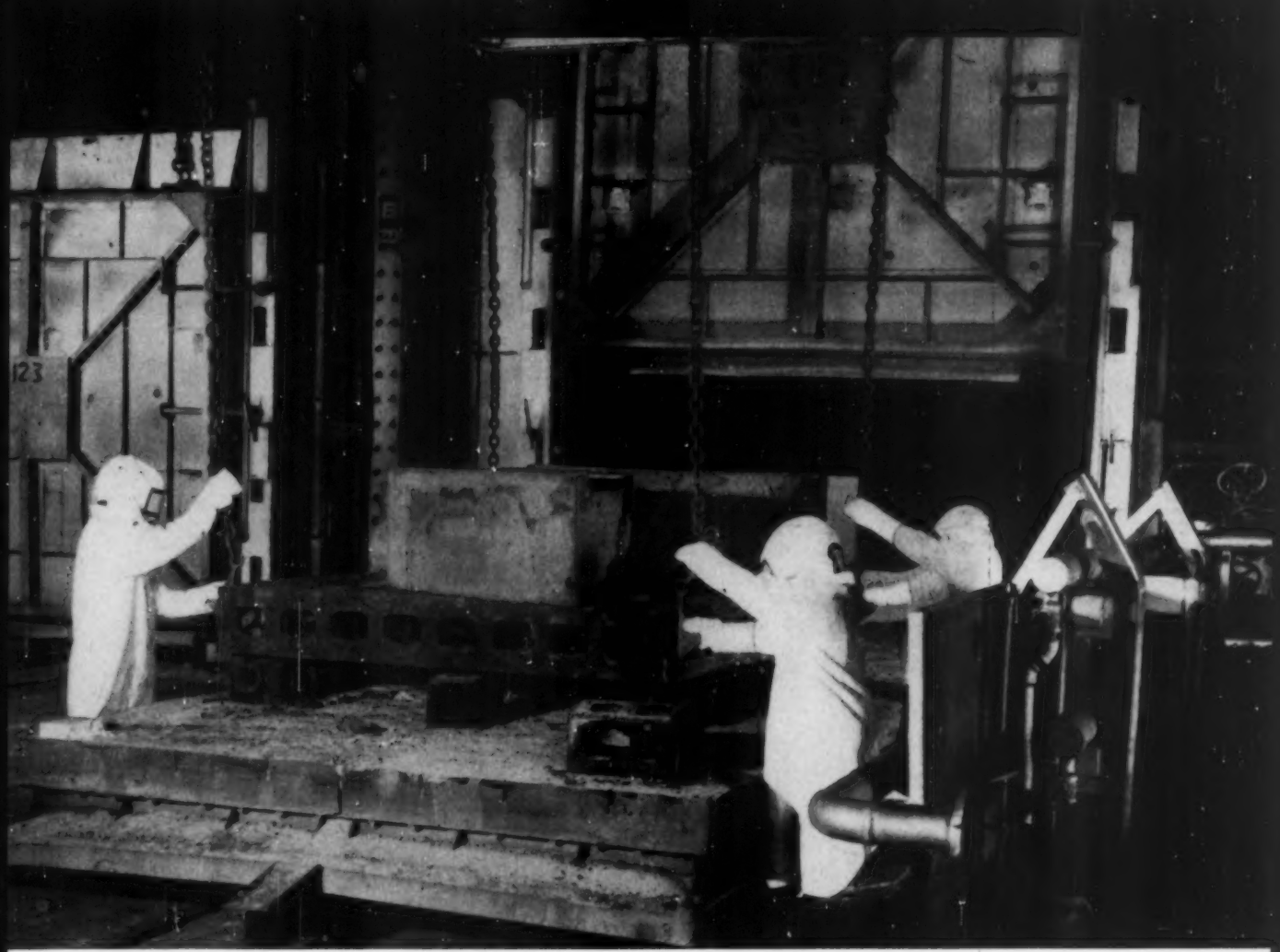


Latch-in fault indicator . . . is a ¾-in., sealed, magnetic unit to be available in wide current and voltage ranges. A disk-type flag, which may be color coded or imprinted to designate function being monitored, rotates behind a sector window. When not energized, flag is magnetically held in "off" position. When energized, it rotates to "on" position and is held there magnetically even if energizing source is removed. Return to normal "off" position is accomplished by reversing polarity of energizing source. Unit maintains positive indication even when unenergized under vibration from 10 to 500 c at 10 g. Reportedly available by early October. **Minneapolis-Honeywell Regulator Co, Precision Meter Div, Grenier Field, Manchester, NH.**

Circle 313 on Reader Service Card

Multipurpose transistor . . . is capable of high performance over wide range of applications and circuit requirements. Made possible by triple diffusion and planar manufacturing techniques, unit is said to perform

continued, page 129



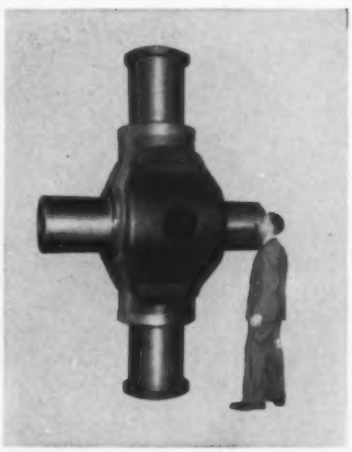
Blaw-Knox Steel Foundries have the heat treating capacity to handle the largest casting

Your steel casting gets precisely the characteristics of uniform hardness, toughness, or temper you specify in a Blaw-Knox Steel Foundry. Blaw-Knox Steel Foundries are equipped with huge pit-type furnaces—some as large as 42 feet × 20 feet × 13 feet deep, and banks of car type furnaces to accommodate the largest steel casting or batches of smaller ones.

Quench tanks as large as 21 feet × 12 feet and 8 feet deep are available, and all Blaw-Knox Steel Foundries are equipped for spray quenching in which specific areas of steel castings are given special quenching. Further flame hardening or other hardening procedures are provided to meet your exact requirements.

Complete heat treating, quenching, and hardening is another way in which Blaw-Knox Steel Casting Service adds value to your product. Blaw-Knox, as one of the world's leading rolling mill and industrial machinery builders, keeps a sharp eye on the end-use requirements of a casting from start to finish. It's your assurance of a component of the highest quality, made for maximum service.

If you design or build products using cast steel components, ranging from 50 pounds to 300,000 pounds, Blaw-Knox would like you to have a copy of our brochure detailing Blaw-Knox Steel Castings Service. Write to the Foundry and Mill Machinery Division, 300 Sixth Avenue, Pittsburgh 22, Pennsylvania. No obligation of course.



This main axle casting for the 60-cubic yard Mountaineer Shovel was cast in a Blaw-Knox Steel Foundry. Wt.—18,000 lbs.

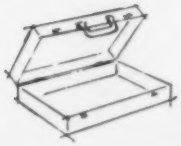
BLAW-KNOX

Steel Castings

CIRCLE 127 ON READER SERVICE CARD

A. O. SMITH HAS THE HORSES...

HURDLE THORNY APPLICATION PROBLEMS



From the case of the A. O. Smith Motor Man

...a line of 800 to 1 hp favorites, built to make tough application problems seem easy

When it comes to building integral-motor-powered equipment, *make sure of your horsepower source!* Before you specify any motor brand, consult with your A. O. Smith Motor Man. He'll show you how the horses of A. O. Smith (single-phase integrals — 1-5 hp — polyphase — 1-800 hp) help users surmount application barriers.

And A. O. Smith delivers the horses that deliver the goods!

COPYRIGHT 1960, A. O. SMITH CORP.

Through research ... a better way

A.O.Smith
CORPORATION
ELECTRIC MOTORS
Tipp City, Ohio

A. O. SMITH INTERNATIONAL S. A.
Milwaukee 1, Wisconsin, U. S. A.

A CASE IN POINT

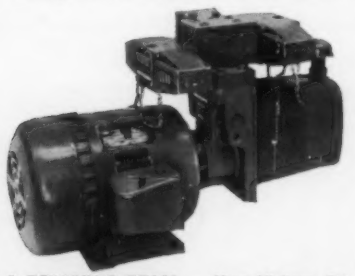
A TEAM THAT PULLS TOGETHER

Latest development in the industrial line of Vickers Inc. (Division of Sperry Rand Corporation) is its new PK line of motorized hydraulic power packages. These versatile units have a wide range of use on small machine tools, presses, paper machinery, textile machines plus countless other industrial applications.

Being "Jacks of all trades" PK power packs required a motor that would team up efficiently for all kinds of service—a motor that could operate on unusual applications yet still be custom-engineered for the particular job it had to do. Vickers had to be particular — that's why they chose A. O. Smith totally enclosed fan cooled motors.

A. O. Smith motors are current choices wherever a simple, compact, powerful unit is needed—in the case of Vickers PK, a motor built for years of reliable hydraulic power and control. Simple and compact because the entire package is close-coupled . . . with splined motor shaft for ease of assembly and disassembly. Reliable because of exclusive A. O. Smith TEFC features — die cast rotor, efficient cooling system, permanently lubricated bearings, reserve insulation protection.

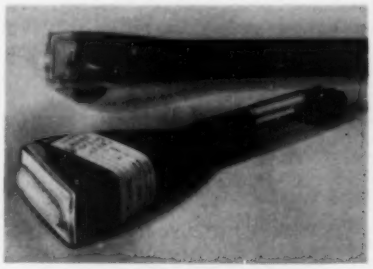
You'll find it pays to team up with A. O. Smith motors — mechanically and electrically, you get more for your motor dollar when you put your money on the horses of A. O. Smith.



A RELIABLE TEAM — New Vickers PK motorized power pack powered by an A. O. Smith TEFC motor — a combination that runs without a hitch.

jobs of up to 40% of more than 2000 transistor types available. Has operating temperature range of −85 to 392 F; switching speed (non-saturating mode) of 30 nanosec max; collector to base voltage, 120 v max; and collector current, 1 amp max. Scheduled for commercial introduction this month, unit is expected to sell initially in the $12 range in production quantities. **Radio Corp of America, Semiconductor & Materials Div, Somerville, NJ.**

Circle 314 on Reader Service Card

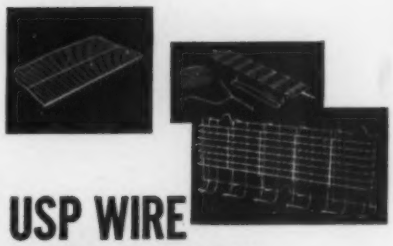


Fiber optics cathode ray tube displays or records digital information directly from tube face without use of conventional lenses and at speeds up to 50 times faster than possible with a lens system. Available with electrostatic deflection and focus or electromagnetic deflection and focus, both with active fiber optics areas of 2¾ x ¼ in. composed of 1-mil fibers on 1-mil centers. Expected to be used for high speed data print and for computers and associated devices. It is reportedly possible to produce characters and pictures through use of line scan techniques or by step printing a long narrow area. From stock beginning Oct 1 at $795 for electrostatic deflection and focus unit and $995 for high resolution unit with electromagnetic deflection and focus. **American Optical Co, Southbridge, Mass.**

Circle 315 on Reader Service Card

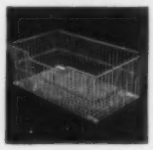
Solid state impulse counter . . . uses a variable dividing principle. Provides a pre-settable, count-controlled output impulse on each tenth input pulse. Count can be changed, as desired, to a nine, eight, seven, down to a two or one-count. Units can be coupled directly in tandem for number or word structure. In tandem, device counts systems of full binary, binary coded decimal, base ten, through base three, etc. Also can perform in a divisional mode. Unit is approx match box size with four pro-

continued, page 132



USP WIRE COMPONENTS . . . do the job better

Why? Because . . . modern wire is the preferred material thanks to its styling versatility, strength, lasting beauty and durability. Because . . . wire, welded in the required shape and size, plated in the finish desired, is fundamentally essential to the appeal, sales and satisfaction of *your product.* Better yet, wire components are comparably more economical!



So . . . if you are planning a product in which you can efficiently utilize welded-wire components, remember . . . designing, fabrication and finishing is our business; as it has been for over 60 years. Anything . . . made of wire to your specifications.

Make your manufacturing dollar go further. Call Union Steel for immediate service—today!

UNION STEEL PRODUCTS CO.
510 N. Berrien Street
Albion, Michigan

USP

Since 1903

Which of these parts should be investment cast?

. . . *All* the parts except the milling machine collet at the top right—which is a "natural" for conventional lathe work. Even the helical impeller the men are examining is best made as an investment casting—the helix is undercut in such a way that no cutting tool could reach inside to remove the metal.

"Naturals" for investment casting are usually parts that are too intricate to be made economically by any other process, or involve alloys or quantities that make them impractical to produce by other methods. In other words, when it looks as if you might have to sacrifice a design because its complexity makes the cost prohibitive, or forego a preferred alloy because it is difficult to machine, then it's time to take a long, hard look at investment casting.

But . . . it's not always as easy as it sounds to spot the parts that are "made" for investment casting. That's where the Arwood sales engineer comes in. He knows Arwood expects him to show a customer how to get the most from the process. To help keep your cost down he may have to suggest a filleted radius here . . . or a tolerance opened up there. Then too, on occasion he may readily have to admit the part should not be investment cast at all. However, he also knows that if you just can't have the part made any other way, Arwood will go all the way down the line to have it investment cast for you.

Our five plants cast every castable metal and alloy, including magnesium and superalloys. Each has its own research, tooling, quality control and production facilities. In short, if it can be investment cast, we can investment cast it.

LIKE TO LEARN MORE ABOUT INVESTMENT CASTING?

Write us for a complimentary copy of our 44-page manual, "Practical Guide to Investment Casting." Among other sections it includes practical tips on designing for investment casting, as well as analyses and physical and mechanical properties of all the metals and alloys cast by Arwood.

Machine the simple . . . cast the complex

A complete service from design through tooling, production and finish machining. Seventy-one engineering representatives from coast to coast.

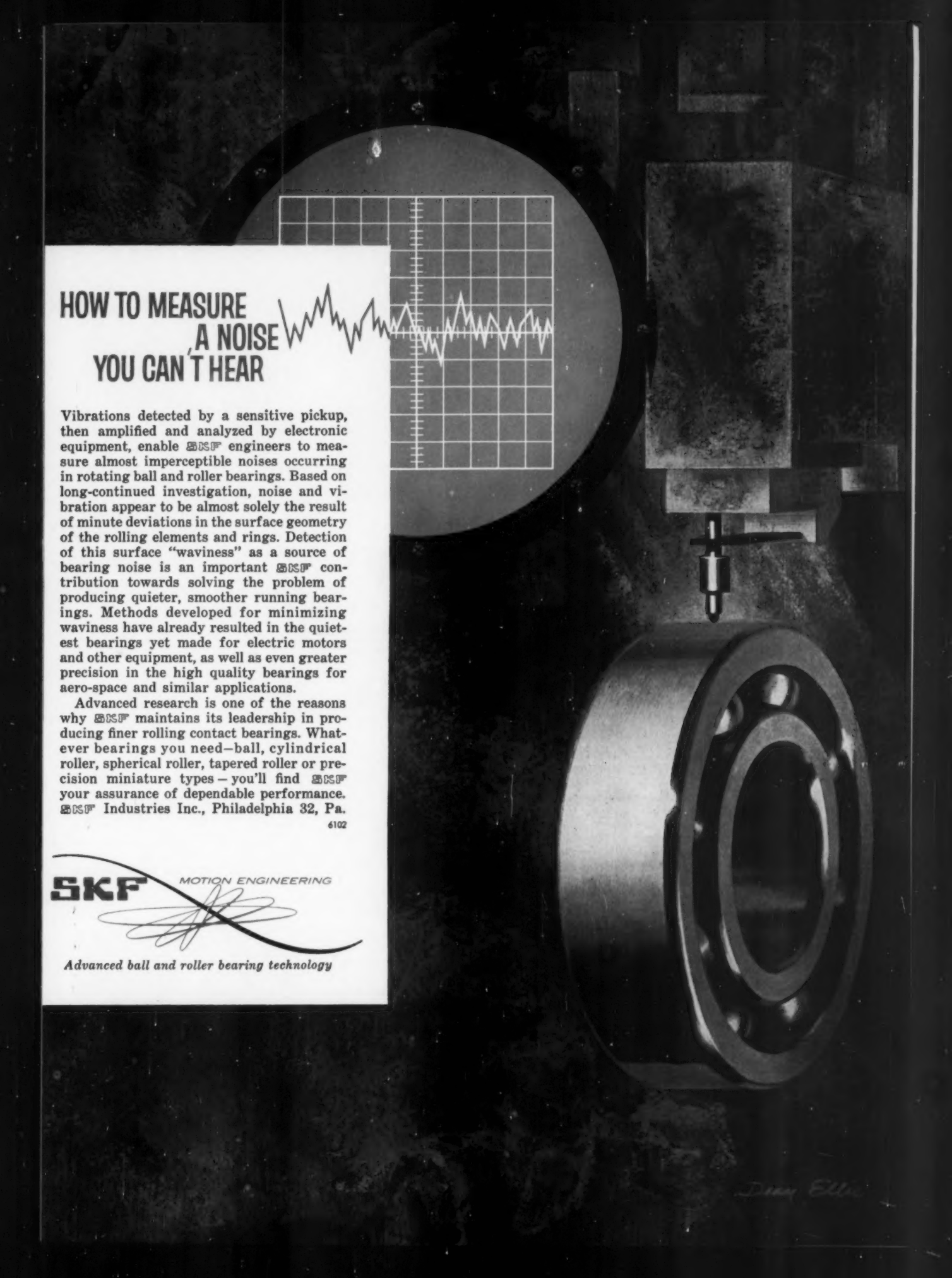
arwood

ARWOOD CORPORATION • **325 West 44th Street, New York 36, New York**

PLANTS IN BROOKLYN, N. Y.; TILTON, N. H.; GROTON, CONN.; LOS ANGELES AND LA VERNE, CALIF.

130 CIRCLE 130 ON READER SERVICE CARD

CIRCLE 131 ON READER SERVICE CARD→



HOW TO MEASURE A NOISE YOU CAN'T HEAR

Vibrations detected by a sensitive pickup, then amplified and analyzed by electronic equipment, enable SKF engineers to measure almost imperceptible noises occurring in rotating ball and roller bearings. Based on long-continued investigation, noise and vibration appear to be almost solely the result of minute deviations in the surface geometry of the rolling elements and rings. Detection of this surface "waviness" as a source of bearing noise is an important SKF contribution towards solving the problem of producing quieter, smoother running bearings. Methods developed for minimizing waviness have already resulted in the quietest bearings yet made for electric motors and other equipment, as well as even greater precision in the high quality bearings for aero-space and similar applications.

Advanced research is one of the reasons why SKF maintains its leadership in producing finer rolling contact bearings. Whatever bearings you need—ball, cylindrical roller, spherical roller, tapered roller or precision miniature types – you'll find SKF your assurance of dependable performance. SKF Industries Inc., Philadelphia 32, Pa.

6102

SKF MOTION ENGINEERING

Advanced ball and roller bearing technology

IDEAL FOR AUTOMATED MACHINES

Maxitorq
ELECTRIC
CLUTCHES and BRAKES

Incorporating advanced design principles proved through years of service, the MAXITORQ Electric Clutch is well adapted to all types of machine drives. Simple in design . . . built to machine tool standards . . . requires no adjustments, can be used either as a clutch or brake. Disc separators not only separate discs, but also break up residual magnetism and result in extremely fast, positive action with no drag or heating in neutral. There are few moving parts. Electrical operating unit remains stationary — hence, no troublesome slip rings, brushes, or difficult wiring problems. Operation is on standard 100 V d.c. Other voltages on special order.

If you have a clutch or brake application where you are looking for NEW and IMPROVED performance, we invite you to bring the problem to us. Phone, wire, or write Dept. PE for Bulletin No. 90.

SPECIAL FEATURES

Engaged entirely by magnetic flux.

Operate either on-off or by varying voltage for torque control.

NO troublesome slip rings or brushes.

NO levers, cams, or other highly stressed mechanical parts.

Operation is not dependent upon rotation.

Finished complete, assembled, and ready to install on shaft.

THE CARLYLE JOHNSON MACHINE CO.
MANCHESTER, CONN.

IC161

jecting pins. Operates at −6 to −10 v dc; has frequency of 10-30,000 cps; and input trigger pulse and output pulse of 0.5 to 1 microsec. Drift is 0 within 5° of ambient temperature. **Vector Mfg Co Inc, Commercial & Industrial Div, Dept 41-79, Southampton, Penna.**

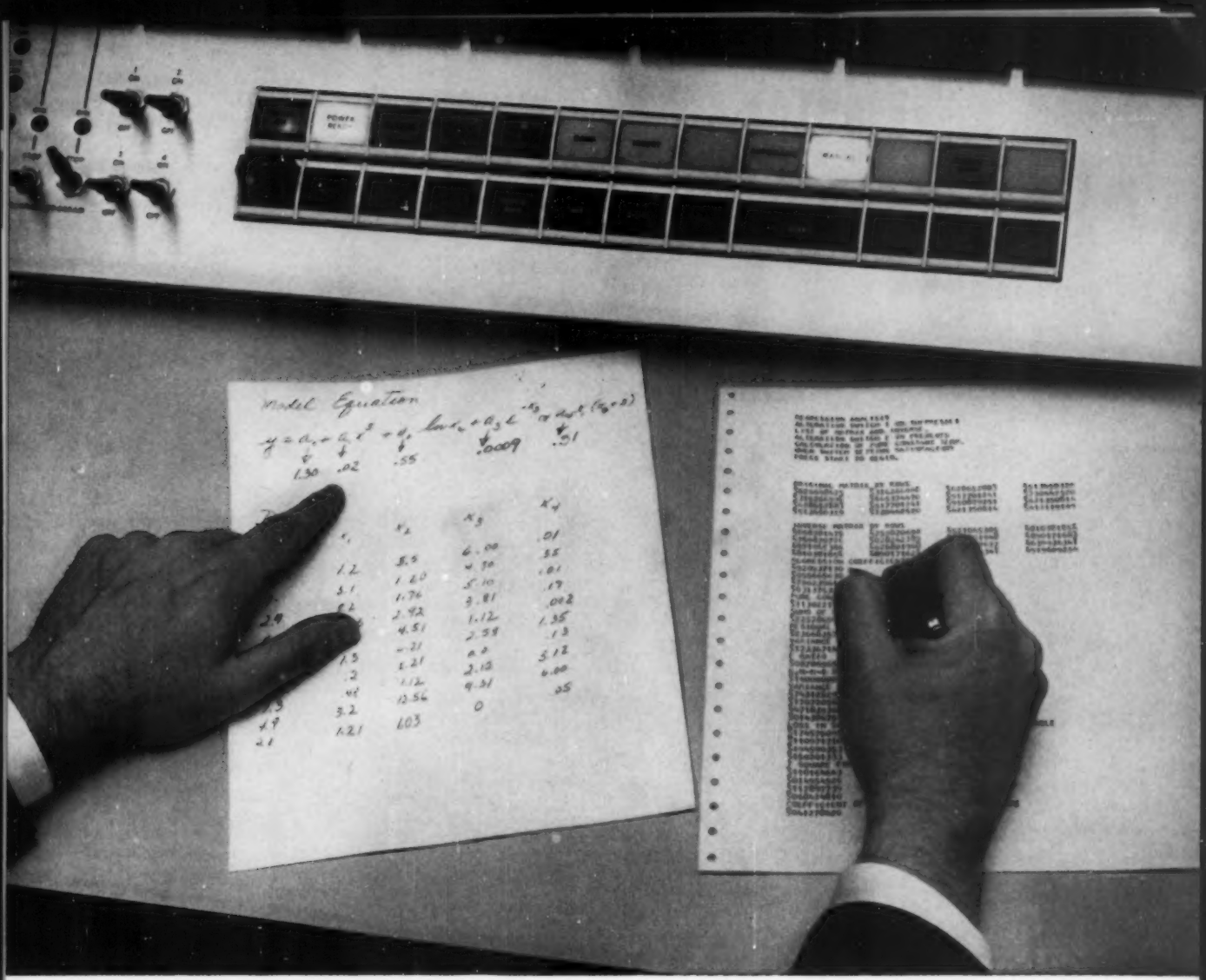
Circle 316 on Reader Service Card

Divider-combiner valve . . . is useful where two hydraulic actuators are required to operate in unison. As a divider, valve divides pump output (up to 40 gpm) into two equal flows (for simultaneous operation of two cylinders, for example). As a combiner, valve equalizes return flows of two cylinders to equalize piston speeds. One or both divided flows can be redivided with additional valves to synchronize multiple elements. Neither constant flow rate nor constant pressure is required for valve's proper functioning. Pump output is divided or cylinder return combined in preset ratio regardless of load or total flow. Cylinders are permitted to synchronize at end of each stroke to prevent cumulative error. Available with one 1-in. NPTF port and two ¾-in. NPTF port. Recommended for pressures to 3000 psi. Weighs 2.4 lb. **Waterman Hydraulics Corp, 725 Custer Ave, Evanston, Ill.**

Circle 317 on Reader Service Card

Self-sealing quick connector has integral pressure-relief valve that safeguards disconnected systems against damage from heat-caused fluid expansion and eliminates auxiliary expansion valves in fluid sub-system. Valves can be supplied for either or both halves of connector. Operat-

continued, page 134



Want to find the coefficients? It's easy with the new Regression Analysis program for the IBM 1620

Here's another program offered free-of-charge to users of the IBM 1620 Data Processing System. It gives you the kind of results you might expect only from a much more expensive computer. But users of the 1620 know that its low rental cost is deceptive. The 1620 packs *more computing power per cubic inch* than any other computer in its size range.

The Regression Analysis program is a good example. Suppose you want a fit for production purposes. If you employ more than two variables you probably have difficulty visualizing the representation of your data. If linearity is not the case, you must often guess blindly at a polynomial of high degree, accept or reject the fit with something approaching a sixth sense, and either try again or settle for the results you have.

The new Regression Analysis program lets you handle expressions containing up to *24 variables*. If you have the even more complicated task of handling many dependent variables, the program will generate regression coefficients with a maximum number of dependent variables not exceeding one-half the number of independent variables.

This program will also fit non-linear functions and hyper-surfaces. Compare this performance with that of any other computer in the 1620's price range.

A basic 1620 installation rents for just $1600 per month. For details, contact your local IBM Representative.

IBM's 1620 is a compact desk-size computer.

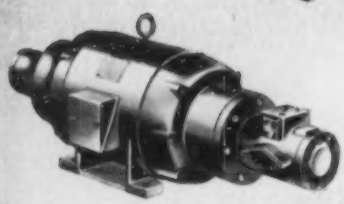
IBM®
DATA PROCESSING

CIRCLE 133 ON READER SERVICE CARD

BURGMASTER USES THESE VICKERS COMPONENTS

POWER PACKAGES—A complete Vickers 30-gallon hydraulic power supply was custom-designed and built for this machine. Vickers offers standard and custom power packages to meet every type of application need. Get details from your Vickers application engineer.

DIRECTIONAL VALVES—Two types of directional valves—solenoid operated and solenoid controlled, pilot operated—are used on this Burgmaster machine. The complete Vickers line of two- and four-way directional control valves is described in Catalog 5001C.



MINIATURE DIRECTIONAL CONTROLS—Series D1L two and four-way valves are designed for low volume systems, are suitable for operation to 1000 psi and have 2 gpm capacity. Low current a-c and d-c solenoids are available in all standard voltages. Write for data sheet D1L-1.

MOTOR PUMPS—A 5 HP, double-end motor pump is used on this Burgmaster. The complete Vickers motor pump line offers single, double, two-pressure and two-stage pumps. Use of these motor pumps conserves space and eliminates alignment problems between pump and motor. Details are available in Catalog 5001C.

VICKERS®

VICKERS INCORPORATED

DIVISION OF SPERRY RAND CORPORATION

Machinery Hydraulics Division

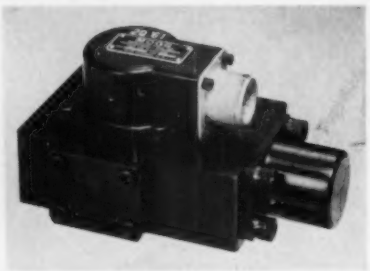
ADMINISTRATIVE and ENGINEERING CENTER

Department 1454 • Detroit 32, Michigan

9794

ing only when coupling is disconnected, valve opens at 60 psi pressure differential. Has max flow of 0.33 gpm and is available on connectors from ½- to 1½-in. line size. **E B Wiggins Oil Tool Co, 3424 E Olympic Blvd, Los Angeles 23.**

Circle 318 on Reader Service Card



Mechanical feedback servovalve . . . is available in flow ratings of 1, 2½, 5, 10 and 15 gpm at 1000 psi pressure drop and max signal. Overcomes oil contamination by: high spool positioning force provided through use of internal mechanical feedback; large replaceable pilot-stage filter; and optional separate pilot supply port to enable use of a second oil supply which may be at a high pressure and subject to more filtration than second-stage supply. Internal mechanical feedback also provides for positioning of spool in proportion to electric signal with a reportedly high degree of accuracy. Also said to improve hysteresis and resolution. Unit is pilot-operated, closed center, 4-way sliding spool valve with symmetrical design that minimizes null shift resulting from pressure or temperature changes. From stock. **Moog Servocontrols Inc, East Aurora, NY.**

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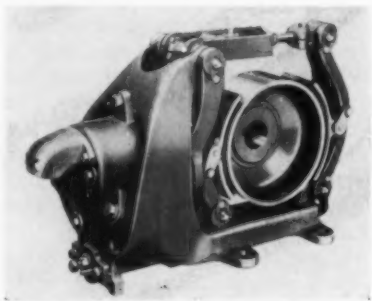
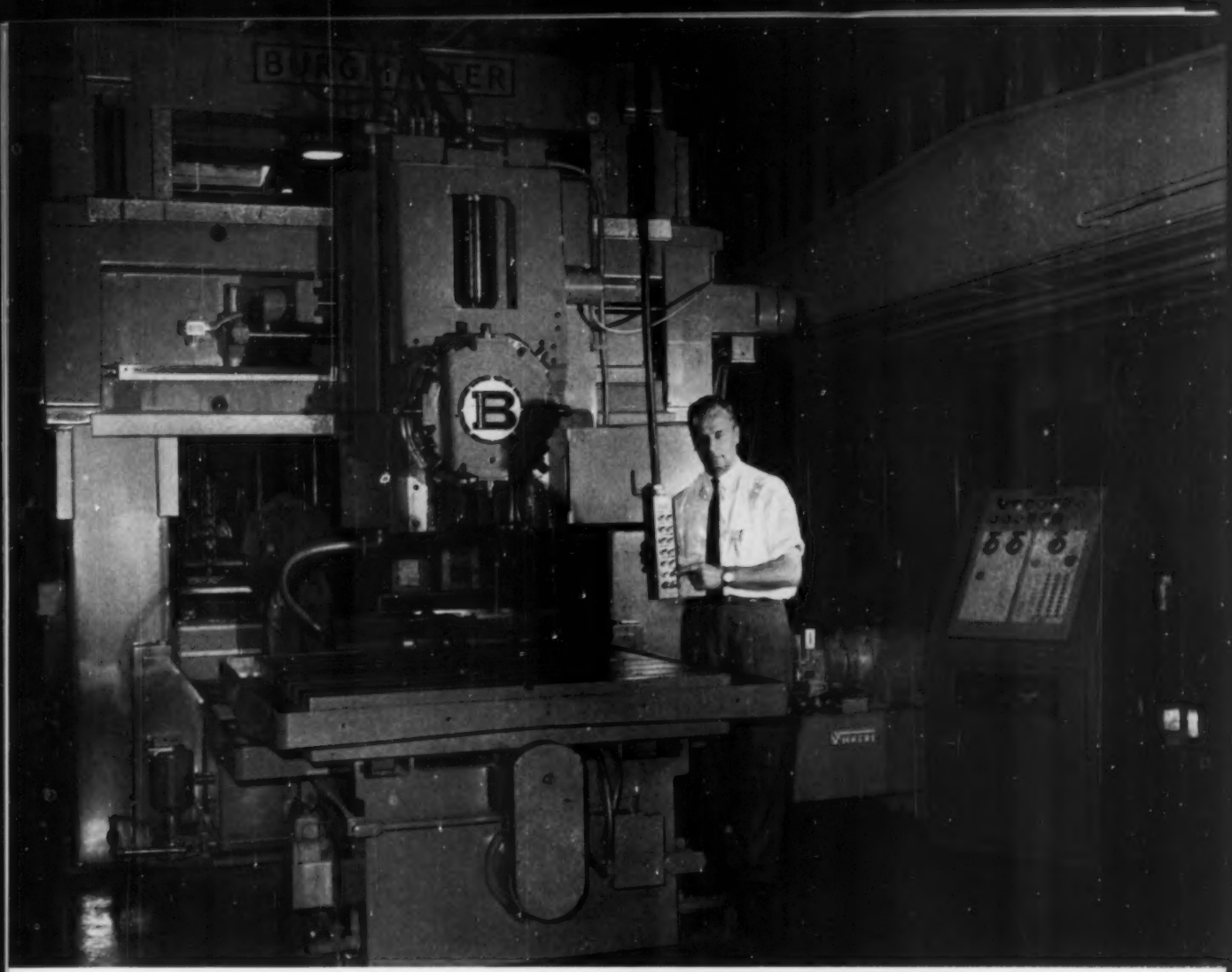


8-in. shoe brake . . . is a dc magnetic unit built to AISE-NEMA standards for 600 series mill motors. Uses "nutcracker" principle of operation, in which equal pressure is applied against the wheel

continued, page 141



ANTTI RAIHA, CHIEF ENGINEER, BURGMASTER CORP. SAYS:

"Hydraulic and tape controlled turret drills need sensitive, reliable power systems..."

". . . in order to control tool penetration and table positioning where location tolerances must be held to .001-inch. We've worked with Vickers hydraulic power systems since 1951, beginning with our automatic hydraulic models, we are increasing our activity in this area as the demand for turret drilling machines and tape controlled machines grows.

"In addition to the machine shown, we use Vickers hydraulics on seven different standard models as well as on many specially designed variations of these standard machines. We rely on Vickers hydraulic power systems, not only for their unusually high quality, but because they are easy to maintain and we have the additional assurance of the availability of their worldwide service organization.

"Because Vickers application engineers have given us close cooperation and have a thorough understanding of our requirements, we've been able to develop systems that provide long, trouble-free life."

Whether you are building standard or special purpose machinery, your power and control requirements can be met precisely and economically by the proper application of hydraulic systems. Typical Vickers components and systems used by Burgmaster are shown on the facing page. They are part of the broadest line of top quality hydraulics available anywhere.

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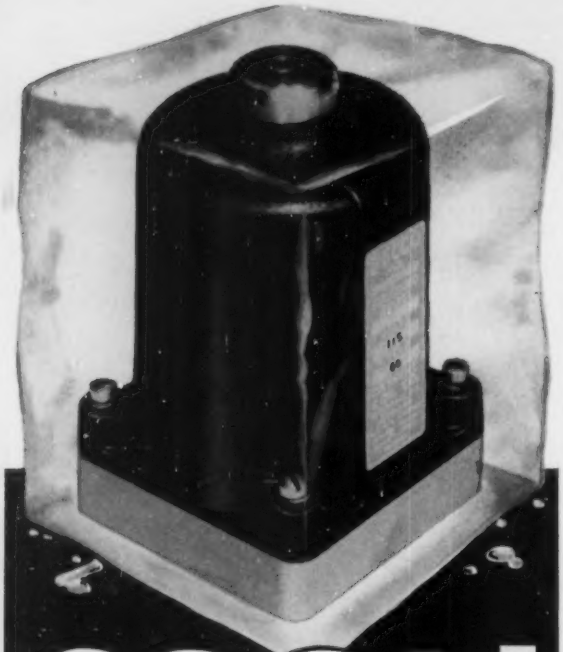

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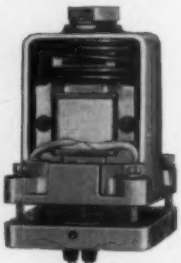
Decco Oil-Immersed Solenoids incorporate all the best mechanical features of Decco Standard Solenoids. Their convenient, plug-in base allows split-second replacement in case of a change in power requirements, and they are designed to comply with J.I.C. specifications.

Decco Standard Solenoids are manufactured in a complete range of sizes and types. Write for complete information.



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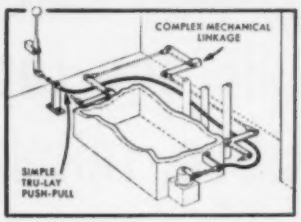
TRU-LAY PUSH-PULL DATA FILE SHOWS HOW TO SIMPLIFY AND IMPROVE DESIGN



Push-Pull remote controls, shown here, are flexible, have but one moving part, and give a lifetime of accuracy. Mechanical linkages are complex, are made of many parts, wear at many points, and produce increased backlash, lost accuracy, and vibration rattles.

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CIRCLE 136 ON READER SERVICE CARD

CIRCLE 66 ON READER SERVICE CARD

Your turn

...to participate in the current problems of our profession.

Do you always have to use the exact formula—or will a close approximation do? You're going to wind up using a sliderule or reading figures off a graph in any case—and these have built-in inaccuracies—so why not take the easy way? **Consider the ellipse.** Finding its perimeter requires the solution of a series as long as your arm—longer if you've got the patience. This is all avoided if you use the method offered by S Kravitz, consultant of Dover, NJ. Here's how he does it:

Example: What is the perimeter of an ellipse that has axes 12 and 20 in. long?

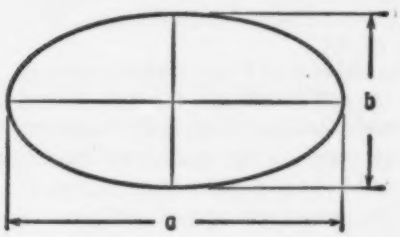
Solution: Enter the curve with the ratio: $b/a = 12/20 = 0.6$. Now find $p/2a = 1.275$

Then multiply both sides of the equation by 2a to arrive at the answer $p = 2 \times 20 \times 1.275 = 51$ in.

Now try a problem or two on your own. And when the curve isn't available, use this equation:

$$p = 2a\,[1 + 0.570\,(b/a)^k]$$
$$k = 1.550 - 0.217\,(b/a)$$

Error in this approximation is less than ⅛%. The further assumption that $k = 3/2$ speeds calculation, but increases error to ⅞%.



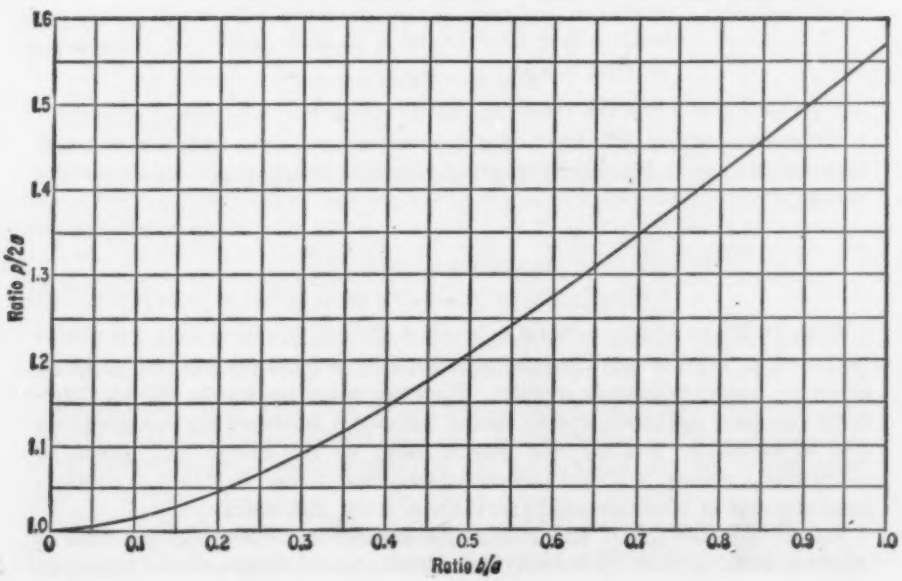
SYMBOLS

a = Major axis of the ellipse

b = Minor axis of the ellipse

k = Variable exponent

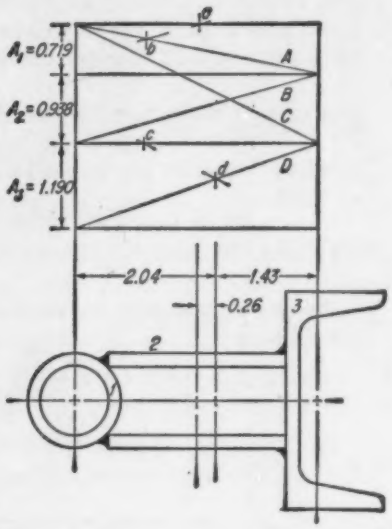
p = Perimeter of ellipse



This idea of developing a close approximation rather than an exact formula applies to graphical solutions too. Sometimes they're more accurate, quicker, and less subject to error than algebra could hope to be. Here's a method to find the **moment of inertia of a complex part** based on a simple graphical procedure. It was worked out by G H Stram, consultant of Hellam, Penna.

As a trial-piece, consider a built-up section made of 1-in. extra-heavy pipe, two pieces of plate and a channel. The step-by-step procedure:

1. Draw the section; split it up into simple component shapes and label them 1, 2 and 3.



2. Find the neutral axis of each component. The vertical neutral axis of the channel is not immediately apparent, but the channel is standard so look up axis location in a handbook. Similarly, calculate or look up areas and moments of inertia for the pipe and for the two plates.

3. Extend the two outer neutral axes. On one measure off, to some convenient scale, lengths proportional to the areas of the three components. Through the points so marked draw horizontal lines connecting the two axes. Project the neutral axis of 2, an axis of symmetry in this case, to the top horizontal (point *a*).

4. Draw diagonals *A*, *B*, *C*, and *D*. Draw another diagonal through point *a* parallel to diagonal *B* until it crosses diagonal *A* (point *b*). Point *b* locates the neutral axis of 1 and 2 taken together.

5. Repeat the same method for (1 + 2) and 3 to locate the neutral axis for the whole section. The neutral axis just found crosses the horizontal between the lines for A_3 and $(A_1 + A_2)$ at *c*. Through *c* draw a line parallel to diagonal *C* cutting diagonal *D* at point *d* to locate the neutral axis for the whole section.

6. Measure the distance (x_1, x_2, x_3) of the neutral axis of each component from the neutral axis of the whole section. Square the distances; then multiply by the corresponding areas. Moment of inertia for the whole section

$$I = (I_1 + I_2 + I_3) + (A_1 x_1^2 + A_2 x_2^2 + A_3 x_3^2)$$
$$= 0.803 + 6.06$$
$$= 6.863$$

Dimensions, of course, are in.^{4} since these are area moments of inertia. For uniform sections simply multiply by length and material density to get mass movement of inertia.

• • • •

Math problems dealing with rates, or rates of rates (accelerations), are always expressed in terms of a differential equation. Some of these are easy to solve; others are almost hopelessly complex. **However, many apparently difficult differential equations can be cracked by special techniques developed for that particular type of equation.** For the next several issues we will review nine classes of differential equations that have elementary solutions. Robert P. Benedict, development engineer at Westinghouse Electric Corp, is our instructor.

But for this first lesson, **let's look at the features that distinguish one class of equation from another:** An ordinary differential equation is an equation having an

independent variable, a dependent variable, and one or more derivatives of the dependent variable with respect to the independent variable, as

$$y' + \frac{3}{x}y = \frac{\sin x}{x^2}$$

$$y'' + 2y' + y = e^x$$

where x is the independent variable and y is the dependent variable. The symbol y' signifies the derivative of y with respect to x, and is the limiting value of the special function

$$y' = \lim_{\Delta x \to 0} \frac{f(x + \Delta x) - f(x)}{\Delta x} = f'(x) = \frac{dy}{dx}$$

and

$$y'' = \lim_{\Delta x \to 0} \frac{f'(x + \Delta x) - f'(x)}{\Delta x} = f''(x) = \frac{d^2y}{dx^2}$$

In the equation above, and in all other equations in this series of articles, the symbol f (or F) followed by the independent variable in parenthesis, signifies a function of the independent variable. Thus, $y = f(x)$ is read "y is a function of x" and for every value of the independent variable x, there is a unique value of the dependent variable y.

SOME DEFINITIONS: Differential equations are classified by order, degree, linearity, and homogeneity.

Order of a differential equation is determined by the highest derivative in the equation. The order of a derivative is the number of times the dependent variable is differentiated with respect to the independent variable. The derivative $y'' = d^2y/dx^2$ is a second-order derivative; $y''' = d^3y/dx^3$ is a third-order derivative. Thus, the equation

$$y''' + 3y'' = \cos x$$

is a third-order differential equation and

$$y' + 2xy^2 = 0$$

is a first-order differential equation.

Degree of a differential equation is determined by the highest power of the highest order derivative. Thus

$$(d^2y/dx^2)^2 + 2(dy/dx)^3 + e^x y = 4$$

is a second-degree, third-order differential equation and

$$dy/dx = y^{1/2}$$

is a second-degree, first-order differential equation, because in rationalized form it becomes

$$(dy/dx)^2 - y = 0.$$

Linearity is related to the degree of the equation. An equation is linear if the dependent variable, y, and its derivative, y', occur only to the first degree, and if the dependent variable is not multiplied by its derivatives. Clearly, all differential equations of a degree higher than one are nonlinear, but many first-degree equations are also nonlinear.

$$(x^2 - 3)y' + 3x^2 y = \sin x$$

is a linear, first-degree, first-order differential equation, while

$$(x^2 - 3)y'' + 3x^2 y^2 = \sin x$$

is a nonlinear, first-degree, second-order differential equation.

Homogeneity is a term that means one thing to some mathematicians and another thing to others. In one definition, a first-order differential equation is homogeneous if the factors multiplying the differentials are all of the same degree. Thus,

$$2xy\,y' + (x^2 - y^2) = 0$$

is a homogeneous, nonlinear, first-degree, first-order differential equation because

YOUR TURN *continued*

$2xy$ and $(x^2 - y^2)$ are both second-degree homogeneous functions. But

$$2xy' + (x^2 - y^2) = 0$$

is a nonhomogeneous, nonlinear, first-degree, first-order differential equation because factor $2x$ is not the same degree as factor $(x^2 - y^2)$. This kind of homogeneity applies only to first order equations.

To others (and this is the definition that will be used in this series) homogeneity of a linear differential equation of any order signifies only that $F(x) = 0$ when the equation is in the form $f_o(x)\, d^n y/dx^n + f_1(x)\, d^{n-1}y/d_n x^{n-1} + \ldots + f_n(x)\, y = F(x)$, regardless of the degree of $f_o(x)$ with respect to $f_1(x) \ldots f_n(x)$. Thus,

$$2xy'' + 5x^2y = 0$$

is a homogeneous, linear, first-degree, second-order differential equation and

$$2xy''' + 5x^3y = 1$$

is a nonhomogeneous, linear, first-degree, third-order differential equation.

Now try it yourself: Classify the following differential equations according to order, degree, linearity, and homogeneity (of the second type) if possible:

1. $3y' - y = 2e^x y'$
2. $(x^2 + 2x)\, y'' + x^2 (\tan x)\, y' - 4x = 0$
3. $xyy' + x y^2 + 1 = 0$
4. $2cyy''' + xy'' + (1 - x^2)\, y = 0$

You'll find the answers to these problems on page 163.

• • • •

Real-life problems are not always so easily classified or solved. Sit back and try your imagination on one of these development problems.

Why doesn't someone do something about the intense glare and heat given off by the standard photoflood lamps needed for indoor moviemaking? Still photographers have their answer in the electronic flash. It is fast—so fast that people are less annoyed by the 1/1000-sec light than they are by the slower but less intense throwaway flashbulb. It is cool, and it is an efficient light source. How about some system of popping electronic flashes synchronized with the movie camera shutter? Present capacitor charge-up times might mean that a dozen separate capacitors would have to be used—firing and recharging in sequence. Or how about using the piezoelectric effect now being considered for I C engine ignition? The camera motor might bump a crystal once for each frame—no capacitors, no problems with the flash battery giving out before the main drive motor.

How about a self-sealing cardboard carton? Bob Marie of Hagerstown, Ind, suggests there might be two types; one that has a **one-shot cohesive** on the mating flaps, the other with a **reusable tacky adhesive** that sticks only to iself. The one-shot material could form a permanent seal through chemical action (one chemical on one flap, another on the other).

Now that we buy all sorts of things from vending machines, **why not a new coinage to be universally useful?** Instead of hunting for the proper combination of small coins—and finding you're short one or two—William F Boudreau of Oak Ridge, Tenn, suggests that somebody devise a **pocket counter that could register amounts up to a couple of dollars.**

You insert the end of the counter into the coin slot and **the vending machine subtracts the necessary amount.** When your "credit" is used up, you take the counter to a bank or store, and pay out the couple of dollars to get it "recharged."

byduplicate shoes, which are self-aligning and symmetrical. Both shoes fit either side, either end up. Magnet coil can be changed on the job without dismantling brake. Magnet is hinged at the top with widest part of the air gap at the bottom, so dirt tends to fall through. **Clark Controller Co, 1146 E 152nd St, Cleveland 10.**

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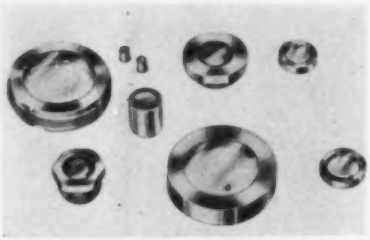

Sealed glass windows . . . with either matched (Kovar) or compression (steel) seals, are suitable for use where visual observation is required inside hermetically sealed electronic, electrical or mechanical equipment. Units with Kovar seals are available in thicknesses of 0.090 to 0.200 in. and with glass OD of 0.150 to 0.300 in. Compression sealed units are available in thicknesses of 0.040 to 0.500 in. and with glass OD from 0.150 in. up. **Electrical Industries, 691 Central Ave, Murray Hill, NJ.**

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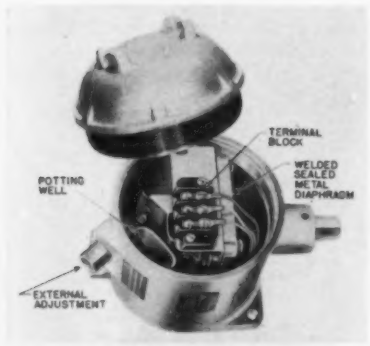
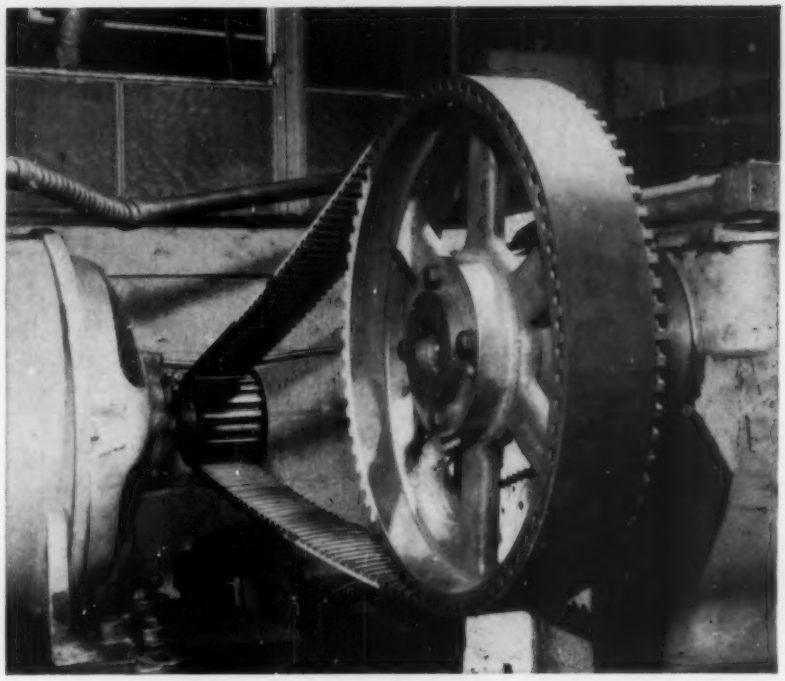


Explosionproof pressure switches have set and reset accuracy with ±½% and can be adjusted externally without exposing circuit. Housings are made with pottable electric outlets and integral terminal blocks for wiring convenience. Diaphragm capsules are removable without interfering with switch wiring and can be interchanged to accommodate varying pressure requirements or fluid characteristics. In low setting, switches actuate at 0.1 in. Hg with proof (test) pressure to 10 psi. In higher ranges,

continued, page 142



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May we show you our references and actual job samples of why these firms keep coming back for more STOKES service? **Write to Thomas E. Wallis, General Sales Manager, Stokes Molded Products, "T"-Street at Webster, Trenton 4, New Jersey.**

P.S. If you want to include a blueprint or drawing with specs, we'll arrive at your office with an estimate you'll really like!

go up to 300 psi proof (test) pressure at settings to 150 psi. Standard pressure connection is ¼-in. NPT female pipe fitting. Available in single setting and dual control models and said to be substantially lower in price than other units. **Barksdale Valves, 5125 Alcoa Ave, Los Angeles 58.**

Circle 322 on Reader Service Card

Limit switch . . .
has 2PDT snap switch which eliminates need for a second limit switch or control relay. Controls up to four circuits and mounts interchangeably with other oil-tight limit switches. Choice of operators includes push rods, roller plungers and roller arms in a variety of lengths and designs. **Square D Co, Dept SA, 4041 N Richards St, Milwaukee 12.**

Circle 323 on Reader Service Card

Power operators . . .
for electrical control drive applications, develop output torques of 30, 60 and 120 ft-lb at ½ rpm. Use of 5-stage gear train allows max output to be achieved in a small package (cast aluminum housing measures approx

6 x 6 x 6 in.). Gear train is immersed in a high dielectric, radioactive-shielding oil, suitable for service from −30 to 200 F. Drive motor, an 1800-rpm reversible split capacitor type, also is immersed in oil. Included are special electromagnetic brakes and cam-operated, silver contact limit switches. Latter replace "cricket-spring" switches found in conventional power operators. **Reliance Instrument Div, Electro-Mech Corp, 500 Livingston St, Norwood, NJ.**

Circle 324 on Reader Service Card

Temperature sensor . . .
has strain-free sensing element mounted directly on inner wall of protective stainless steel well, which is said to permit rapid response. Unit is an immersion-type, platinum resistance temperature sensor with a 0.2-sec time constant and a temperature range from −435 to 500 F. Suitable for use in any fluid compatible with stainless steel well material. **Rosemount Engineering Co, 4900 W 78th St, Minneapolis 24.**

Circle 325 on Reader Service Card

Detent mechanism . . .
originally designed for rotary switches, is a tri-ball, tri-spring unit that reportedly achieves a min of 50,000 cycles and provides greater torque range than two-ball, two-spring index mechanism. Available for 20°-throw, 18-position switches and for 15°-throw, 23-position switches. All parts, except yoke and index springs, are same as those used in two-ball index mechanism. Springs are made of spring brass or stainless steel; yoke is made of brass, cold rolled or stainless steel. Although cycling expectancy is increased five times over two-ball unit, cost of switch using tri-spring, tri-ball mechanism is reported to be increased less than 10¢ per switch in 1000 lots. **Oak Mfg Co, Crystal Lake, Ill.**

Circle 326 on Reader Service Card

continued, page 144

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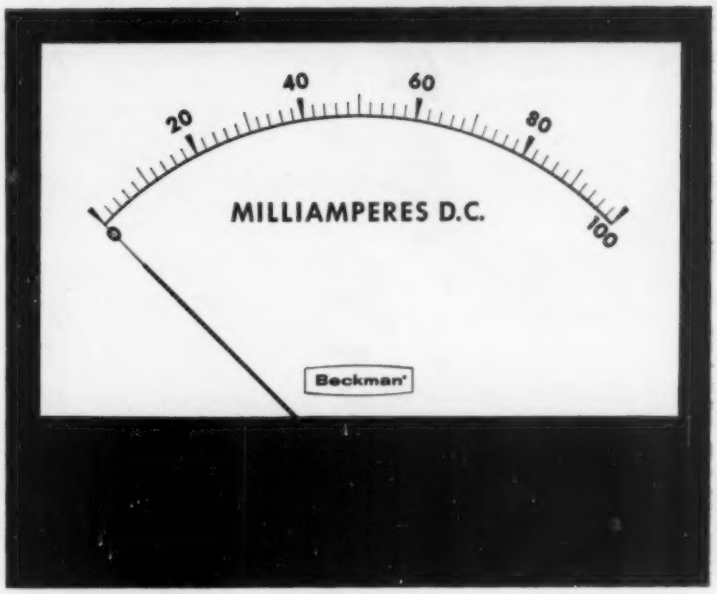
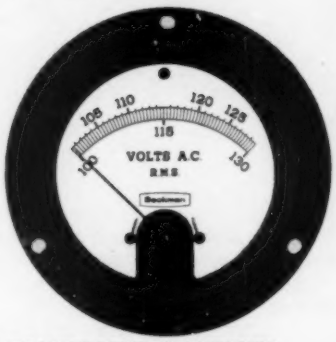


STANDARD PANEL METER
4" x 6" size, 0-100 Milliamps



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- More reliable epoxy encapsulation because CLOSED-BORE design eliminates possibility of distortion or leakage of material into bore.
- Increased possibility of modifications to utilize sealed liners, air bearings, and similar special operating designs.

EMD can furnish stator/rotor components, or specialized motors to your requirements. These are available in custom sizes and ratings, or can be selected from existing standardized diameters from 1¾" to 6⅛" stator O.D., in ratings from sub-fractional thru 20 h.p., in all induction windings, including hysteresis and torque.

Illustration above is unretouched photograph of actual stator cross-section showing extremely compact construction of EMD CLOSED-BORE design.

Write or phone for additional data.

Patents & Patents Pending

EMD Components inc.

1430 EAST 289th ST., WICKLIFFE, CLEVELAND, O.
PHONE: WH. 3-2424

NEW MATERIALS

High-temperature laminates . . . include glass-reinforced phenolic resin and epoxy. Former is designed for applications requiring high insulation properties. Reported to have excellent machining characteristics and to be resistant to temperatures as high as 800 F. Available in thicknesses from 0.125 to 0.750 in. and greater and in sheet sizes ranging from 9 x 10 to 20 x 36 in. Latter grades are unclad and copper clad flame retardant laminates that retain at least 50% of their flexural strength after exposure to 300 F for 1 hr when tested at 300 F. Average min bond strengths are approx 12 lb per in. for 2-oz copper cladding and 10 lb per in. for 1-oz copper cladding. Primarily for printed circuit applications, these laminates are available in popular thicknesses and in sheet sizes 18 x 36 in., 20 x 36 in. and 21 x 36 in. **Mica Corp, 4031 Elenda St, Culver City, Calif.**

Circle 327 on Reader Service Card

Ultra-high strength steel . . . offers tensile strength values above 360,000 psi with safe ductility and maintains strength at temperatures to 1000 F. Also has yield strength (0.2% offset) of 290,000 psi, a reduction in area of 20-30% and an elongation in 2 in. of 6-8%. Can be readily machined or ground and hot- or cold-formed. Expected to find use in bearings and fasteners. Available in bars, forgings, sheet, plate and wire, with a bar base price of $1,865 per lb. **Vanadium-Alloys Steel Co, Latrobe, Penna.**

Circle 328 on Reader Service Card

Metal-filled silicone resins . . . include lead-, bronze-, steel-, copper- and aluminum-filled silicons. Materials are basically rubberlike in character, but with selected metal fillers can be used at very low and very high temperatures. **Furane Plastics Inc, 4516 Brazil St, Los Angeles 39.**

Circle 329 on Reader Service Card

Combined RF, fluid gasketing . . . is comprised of a metal gasket integral with an elastomeric gasket to which pressure-sensitive adhesive has been applied. Installation requires only removal of release material and application of the gasket with normal hand pressure. Currently available with neoprene sponge fluid gasket portion (other materials under development). With the neoprene, adhesive develops a progressively stronger bond so that in 1 to 3 wk, the neoprene will tear before bond separates. However, at time of installation, gasket can be peeled off and replaced in case of a misalignment. **Technical Wire Products Inc, 129 Dermody St, Cranford, NJ.**

Circle 330 on Reader Service Card

Semi-conducting polyethylene . . . used primarily as an electrostatic shield on insulated wire and cables, can be applied as an extruded layer or as wrapped tape. Semi-conducting nature spreads an electrical charge over a large cable area. This distribution reduces chance of a hole being blown in cable jacket. Expected to find use in extruded or molded parts which must be free of static electricity, among other things. Copolymer resists cracking when bent, despite high carbon content. Also exhibits toughness, flexibility at low temperatures, and moisture-, corrosion- and chemical-resistance. **Polychemicals Dept, E I Du Pont De Nemours & Co, Wilmington, Del.**

Circle 331 on Reader Service Card

Conductive epoxy adhesive . . . can be used with three different hardeners to modify handling and operating characteristics. One hardener cures base at room temperature; one provides long pot life; and one is effective at elevated temperatures. Water absorption after 24 hr is 0.1% and shrinkage during cure, 0.15%. Mixed material is a smooth paste filled with silver and when cured yields a volume resistivity of 0.01 ohm-cm at 77 F. Said to be moderately priced. Kit containing one lb base and a room temperature cure hardener is priced at $15. **Conap Inc, 184 E Union St, Allegany, NY.**

Circle 332 on Reader Service Card

High-temperature insulation . . . is a proprietary carbon product for both thermal-insulation and erosion-barrier applications. Said to offer both low thermal conductivity and low ablation rate when combined with phenolic resin and to be compatible with most resin systems and with all reinforced-plastic fabrication techniques. Available in both fiber form and fabric rolls 33 in. wide and 50 yd or more long. Warp breaking strength is reported to be 25 lb/in. or greater. Possible uses include

continued, page 147

Linde Coatings & materials News

LINDE COMPANY, DIVISION OF UNION CARBIDE CORPORATION

Surgical shears get longer life with LINDE tungsten carbide coating

Surgical shears with tungsten carbide coated on working surfaces now lose their cutting edge about *one-third* as fast as conventional shears. This has been proven under rigid testing supervised by a leading research laboratory.

The American Medical Instrument Corporation, Flushing, New York, uses the LINDE Flame-Plating process to improve the working surface and increase the wear-resistance properties of shears produced under its *Tuncarb* trade-mark.

The process has increased cutting life to the extent that *Tuncarb* shears in use for more than a year have not as yet been returned to AMICO for sharpening. By comparison, regular surgical shears used under the same conditions had to be returned as many as three times for restoration of working surfaces.

Coatings only .004" thick

AMICO ships hot-drop-forged stainless steel parts to LINDE's new Flame-Plating plant at North Haven, Conn. Here, via the LINDE developed coating process, a .004" thickness of tungsten carbide is actually "welded" to the precision wear surfaces of the instruments.

After coating, the blades and jaws are assembled, riveted, ground, polished, and buffed to a high finish by AMICO. The tungsten carbide surfaces themselves are finished with only a slight brushing. The same process is used to coat *Tuncarb* needle holders to provide tungsten jaws that give a firm grip on needles.

High-speed "blast-on"

The heart of LINDE's coating process is the LINDE Flame-Plating gun, into which exact quantities of oxygen, acetylene, and tungsten carbide or other powdered materials are fed by a special mechanism. After the gun is aimed at the area to be coated, controlled detonations "blast" the particles onto the work piece at speeds up to 2500 fps—until the desired coating thickness is reached.

Although temperatures of about 6000° F are attained within the detonation gun to heat powder to plastic state, the work piece itself is always kept below 400° F during the operation. There are no changes in the properties of the base metal and no distortion of the work piece regardless of its minuteness.

The inside cutting surface of the *Tuncarb* surgical shears shown here have been coated with tungsten carbide, reducing their rate of wear by as much as one-third.

In some uses, depending on the thickness of finish, the LINDE Flame-Plating process has been known to multiply wear resistance of metal parts by as much as 40 times.

For complete information on how you might use this advanced method of coating metals to improve production or reduce operating costs, check and send the coupon below.

LINDE synthetic sapphire solves guide problem in tape recorders

Second only to the diamond in hardness, LINDE synthetic sapphire provides unique wear-resisting characteristics. Because of its extremely low friction, hardness, and physical and chemical stability, several large manufacturers are using LINDE synthetic sapphire to solve the wear problem in tape guides on airborne and high-reliability tape decks, as well as in photographic film guides.

In these areas—where hardened steel guides show friction and wear almost immediately—sapphire wear is nearly imperceptible even after 100 hours of operation.

LINDE flame-polished synthetic sapphire is a convenient material for preventing edge-cutting typical with certain tapes in top and bottom guides.

For details on LINDE synthetic sapphire for any type of wear guide, instrument bearing, or other critical application, check and mail the coupon.

Chromium polished to maximum lustre with LINDE abrasives

In certain applications where it is necessary to achieve an extremely smooth surface on chromium finishes, such as in photographic rolls and processing rolls in the plastics industry, LINDE alumina abrasive powders of 99.98% purity have demonstrated unusual efficiency in removing the most minute protuberances.

Several leading photographic and precision parts manufacturers use LINDE abrasives, not only to obtain high-lustre finishes that protect materials, but also to refinish rolls several times over to avoid frequent replating.

Grades of LINDE alumina powders in sub-micron sizes are available for several cutting speeds or types of finish. For information, use the coupon below.

CHECK—CLIP COUPON—ATTACH TO BUSINESS LETTERHEAD

Linde Company, Dept. PG-93
270 Park Avenue
New York 17, N. Y.

Please send details on the items checked:

- ☐ LINDE Flame-Plating
- ☐ LINDE Synthetic Sapphire
- ☐ LINDE Alumina Abrasives

UNION CARBIDE

LINDE COMPANY

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CIRCLE 145 ON READER SERVICE CARD

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TRANSMISSION LININGS and special CLUTCH FACINGS

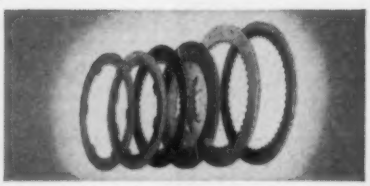
can help you solve design, performance and cost problems with this complete line

TRANSMISSION BAND LINING

Dry-mix, rigid-molded segments can be supplied flat or curved, with or without adhesive and with a variety of grooving patterns.

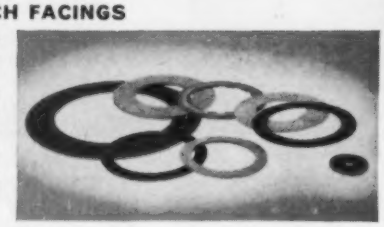
FRICTION DISCS

Paper, cork, rubber-base or dry-mix friction material selected or compounded to meet your requirements and bonded to steel backing plates.



SPECIAL CLUTCH FACINGS

Primarily dry-mix material especially compounded for power tools, home appliances, cameras and other precision devices as well as automotive and industrial equipment.



WORLD BESTOS is one of the few manufacturers that supplies a complete line of O.E.M. approved automatic transmission friction parts for all U.S.-made automobiles. This unusually wide experience plus automated production gives you (1) the lowest possible cost commensurate with the quality required and (2) prompt delivery of special clutch facings and transmission linings that fit and perform as specified. All WORLD BESTOS parts are precision pre-tested and scientifically proved. New four-page brochure No. 1051 lists parts and materials currently in production. For additional information and a copy of the brochure, write or call:

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Industrial and Automotive Brake Blocks and Linings • Transmission Linings • Special Clutch Facings • Vibration Controls • Sheet Packing

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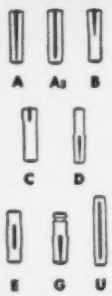
3600 VIBRATIONS A MINUTE

Through millions of minutes

DRIV-LOK PINS
ARE IMMUNE TO FATIGUE



Day after week after year, **Driv-Lok** grooved pins offer tremendous durability and resistance to fatigue, through countless vibrations, shock, and reverse cycling. Better than any other type of pin, including spring types, they stand up. And fatigue is one of the greatest enemies of fastening devices.

Driv-Lok grooved pins cost no more, yet the insurance they provide against fatigue-induced component failure makes them an extremely economical investment. Available from stock in eight standard types, plus a large variety of specials to order, **Driv-Lok** pins can be of real service in solving your fastening problems.

Give us a call, send us a sketch of your problem, or write for your free Driv-Lok catalog. We'd like to be of help.

DRIV-LOK SALES CORPORATION
723 PARK AVE., SYCAMORE 6, ILLINOIS

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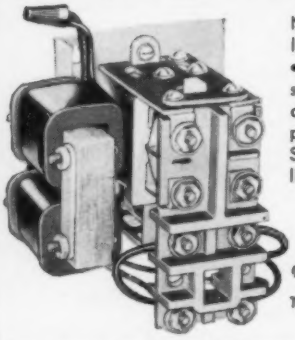
WARRICK
Floatless, Electrode Type
LIQUID LEVEL CONTROLS

give you all these advantages!



No moving parts in the liquid • Easy to install • No adjustments necessary • Unaffected by acids or caustics • Unaffected by pressure or temperature • Standard 2&3 pole units listed by U/L

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electrical insulation, filters for corrosive liquids and vapors, and in dry, non-lubricated bearings, gaskets and packings. **H I Thompson Fiber Glass Co, 1733 Cordova St, Los Angeles.**

Circle 333 on Reader Service Card

Foam joint sealer . . .
is permanently resilient at all stages of compression and under varying conditions of climate and temperature. Even under concentrated loads, it returns to original shape and size within short time after pressure is released. Material is a polyurethane foam, impregnated throughout with asphaltic bitumen. It is said to be watertight, nonstaining (except on place of contact), non-bleeding, unaffected by temperature changes from –54 to 160 F and to have chemical and physical stability, low thermal conductivity, excellent acoustic properties and ease of handling. Its tensile strength is approx 18 psi and it sustains elongation to 435% of original length in uncompressed state when load is applied slowly. Can be compressed to as little as 8% of original volume without rupture. Extent of elastic recovery when all compressive forces are removed is 98% or more. In addition to use as a joint sealer, material is suitable as a thermal and acoustic insulator and as a moisture seal for electrical equipment (because of its cellular structure, should not be used as an electrical insulating material). Available in standard strip form of varying cross sections 6 ft long and in sheets up to 6 ft x 4 ft 6 in. x 4 in. Price per unit volume is said to compare with other top quality caulking and sealing materials. **Asbiton Western Inc, 1491 Daisy Ave, Long Beach 13, Calif.**

Circle 334 on Reader Service Card

Electrically conductive compound
is of fiberglass-reinforced polyester. Parts produced with compound are said to show excellent physical strength and corrosion resistance in addition to complete static draining. Molded parts also require little or no subsequent machining and are lighter than metal. Material is electrically conductive to extent that it will show a zero Megger reading. Has impact strength (IZOD notched) of 5 ft-lb per in.; flexural strength of 16,000 psi; and tensile strength of 5000 psi. Black in color, compound is priced from 63¢ to 69¢ per lb, depending on quantity. **Glastic Corp, 4321 Glenridge Rd, Cleveland 21.**

Circle 335 on Reader Service Card

continued, page 148

Behind your Carbon Brush- IS STEP-BY-STEP TESTING– all the way!

It's not only the willingness to perform tests that counts, but also the experience in depth that interprets those tests and then follows through to match findings with job. With Superior Carbon Brushes you'll get the right price, freedom from trouble, long service and optimum performance for your *specific equipment* under your *specific conditions*. A vast fund of verified field data is yours to command via a Superior representative.

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BRUSHES • CONTACTS • SLIP RING ASSEMBLIES
POWDER METAL PARTS • MECHANICAL CARBONS

CIRCLE 147 ON READER SERVICE CARD

Stewart Ashton, our Chief Engineer, reports on the all-new . . .

pHayes-master (TM)

HERE AT LAST is a simple, compact, space-saving package that provides *microsecond* response for controlling power to electric furnaces . . . and *for numerous other applications* and processes where temperatures must be precisely regulated.

A TRANSISTORIZED UNIT, the new Hayes pHayes-master now replaces costly and bulky saturable core reactors, tubes, magamps, powerstats, etc. — with *one*, small, smartly-designed control unit!

VERSATILE, TOO . . . pHayes-master can be used with most proportioning type temperature instruments . . . handles up to 70 amp. capacities at 220 volts, with stepless control over the full 0-100% range. Highly accurate, pHayes-master provides instantaneous, straight-line response . . . completely without lag or hunting.

ECONOMY is another big advantage. The Hayes pHayes-master features a high power factor—expends only a fraction of the power source for control. Simple rugged construction and circuitry make it far easier and cheaper to install and maintain than conventional control devices.

These are just the highlights. If *your* equipment or process calls for close control of power for heat generation, get the *complete* facts on the all-new Hayes pHayes-master. Write for new Bulletin C-1,or tell us about your application requirements. — C.I.HAYES, INC., 958 Wellington Ave., Cranston 10, R. I.

C. I. HAYES, INC.

Established 1905

ELECTRIC FURNACES

It Pays To See Hayes for metallurgical guidance, lab facilities, furnaces, atmosphere generators, gas and liquid dryers, pHayes-master (TM) control units.

EQUIPMENT

Portable photocopier . . .
is built into an attache case. Can be used in daylight or under artificial lighting conditions and copies any original up to 9 in. wide by any length. Unit's own exposure light source is an 8-w, 12-in. green fluorescent lamp rheostat-controlled by a panel knob to compensate for varying shadings of originals. Case, natural luggage color with brass hardware and dual security locks, measures 17½ x 12¾ x 4¾ in. and weighs 12½ lb. Priced at $149.50 Another model, which has an added bookcopier for use on maps, charts, blueprints and bound volume material, is priced at $199.50. **Anken Chemical & Film Corp, Newton, NJ.**

Circle 336 on Reader Service Card

Drawing table . . .
is combined with reference desk having large, shallow tool and catalog drawers equipped with Nylon bearing suspension and rubber bumpers. Also included are floor levelling tubular legs, brushed chrome handles, three electrical outlets and plastic reference top. Drawing unit has toe-touch pedals which give complete height 30 to 45 in. and angle 0 to 90° from a seated position. **Stacor Equipment Co, 285 Emmet St, Newark 5, NJ.**

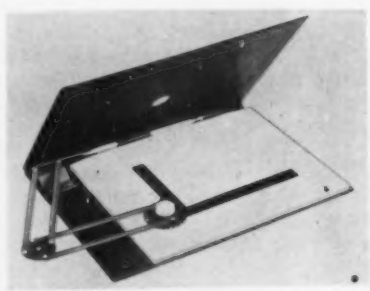
Circle 337 on Reader Service Card

Portable strain indicator . . .
provides digital readout, eliminating interpolation from dials and meters, and gage factor range increased from former range of 1.77 through 2.22 to 1.50 through 4.50. Operates with most strain gages in 1-, 2- or 4-arm networks and with strain gage transducers—bonded or unbonded—to directly indicate the measured variable. Strains are read directly as the sum of the digital counter indication and the "add-to-reading" setting. Gives readings from 0 through 5000 microin. per in. in ¼-in-high white numerals on black background. Range includes 12 intervals from 0 through 60,000 microin. per in. Accuracy is 0.1% of reading, or 5 microin. per in., whichever is greater. Readability is 1 microin. per in. Unit also provides a demodulated output from the scope jack so that dynamic strains—up to 50 cycles per sec and 5000 microin. per in.—can be seen, minus the carrier, on any cathode ray oscilloscope. Weighing 18 lb, indicator is 12 x 8½ x 9½ in. Incorporates transistors and printed circuits, color-coded 5-way binding posts, and is enclosed in a Formica case. **Electronics & Instrumentation Div, Baldwin-Lima-Hamilton Corp, 42 4th Ave, Waltham 54, Mass.**

Circle 338 on Reader Service Card

Diazo print developer . . .
has a heated roller which speeds action of ammonia developer. Also produces completed development on black line prints and sepias. Prints up to 42 in. wide are developed at rate of 48 per min., said to be ten times faster than tube method of development. Weighs 30 lb and is designed for wall mounting or as desk model. **Rotolite Sales Corp, Stirling, NJ.**

Circle 339 on Reader Service Card

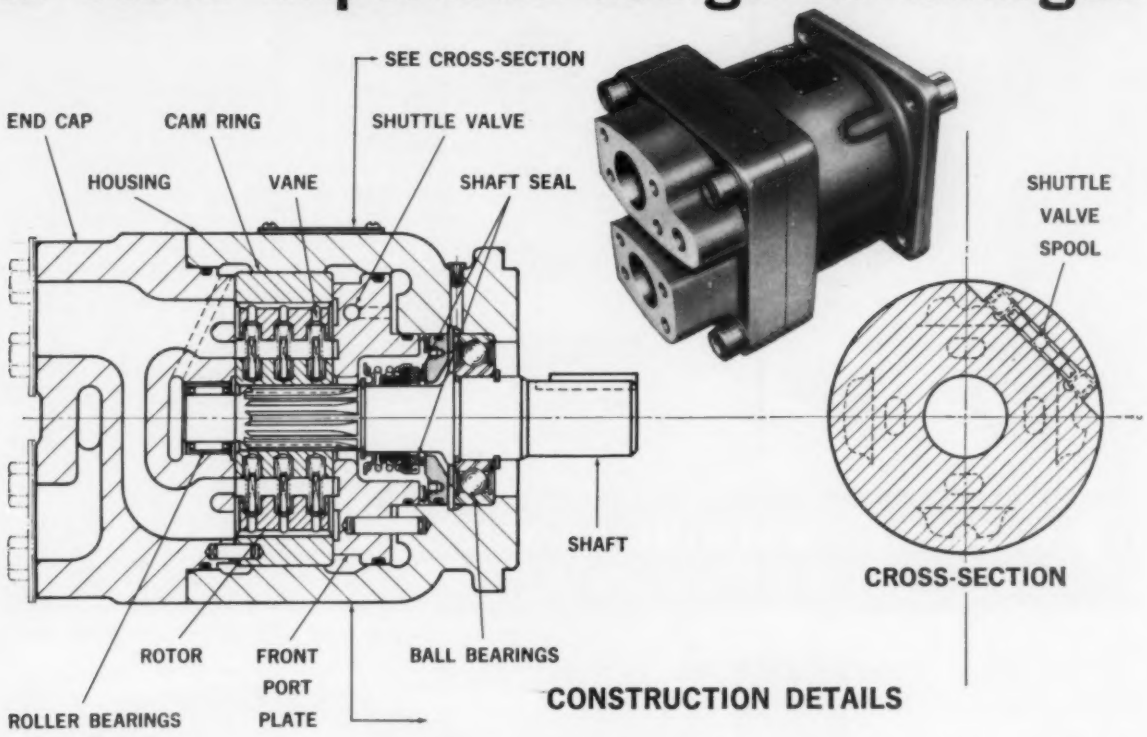


Drafting kit . . .
includes drafting instrument, with 3 x 5-in. or 4 x 6-in. scale and 180° protractor, pad of 50 sheets of 8½ x 11-in. drawing paper and pencil in a vinyl self-locking binder. Portable instrument is said provide advantages of a T-square, triangle and protractor. Kit, measuring 9½ x 13 x 1½ in., weighs 1½ lb. Priced at $8 with small scale and $9 with larger scale. **Draftette Co, PO Box 794, Beverly Hills, Calif.**

Circle 340 on Reader Service Card

FOR HYDRAULIC ROTATING POWER:

New 2000 psi balanced-vane fluid motor has these important design advantages



By: Robert A. Manogue

Pumps/Controls Product Manager
Denison Engineering Division
American Brake Shoe Co.

Today's demands for efficient, low cost hydrostatic power transmissions are growing rapidly. Design engineers have, in turn, demanded reliable vane-type fluid motors that are compact, lightweight and efficient for their hydraulic rotating power needs.

COMPACT 1 LB. PER HP RATIO

The new Denison "M1D" Series floating cartridge, balanced vane/balanced rotor fluid motor shown here is one of 5 sizes available. They are excellent choices for service up to 2000 psi at speeds up to 2000 rpm and for hp ranges up to 75. Unit size is a highly compact 11 11/16" long by 6 1/8" square—including normal keyed shaft extension. Weight is under 75 lbs., affording an efficient 1 lb. per horsepower ratio.

The five motor sizes offer a range of maximum theoretical torques of 1249, 1719, 1897, 2160 and 2345 lb.-in. at 2000 psi.

BALANCED VANES AND ROTOR

The pumping cartridge (vanes, rotor, cam ring, front and rear port plates) offers high efficiency power transmission through the motor shaft by symmetrically balancing the rotor and vanes 100% for axial thrust in both directions. Radial vane balance is approximately 80%—imparting a 20% pressure loading to the vanes as outward force against the cam ring to allow following the cam contour. By a unique combination of spring loading and oil porting control, vanes are balanced outward during their entire pumping period. This balance is produced by a combination of centrifugal force, spring loading and partial pressure loading.

Denison's vane design (two contoured sealing lips) also means effective control of cross-port leakage during work stroke on the major cam ring diameter. This leakage is normally inherent in most other fluid motors.

SHUTTLE VALVE CONTROLS CARTRIDGE LOADING

Clamping forces are imparted to these new M1D fluid motors by a unique shuttle valve, interconnected with the motor's two external ports. This valve shifts automatically to maintain the highest pressure available to the front port plate in order to control motor cartridge clearance axially. This special design always ports highest pressure oil to the rear of the front port plate—providing controlled cartridge loading that gives peak efficiencies and permits starting at any temperature.

FOUR OTHER DESIGN ADVANTAGES

Four other important features of the Denison M1D Series: (1) A 100 psi mechanical shaft seal. (2) Extremely wide bearing spacing to permit full shaft side loading—up to 795 lbs. side load. (3) Angular alignment is achieved by means of snug fit dowel pins. (4) Designed for SAE requirements—including 4-bolt SAE mounting pad, SAE spline shaft and SAE fluid connections. The main motor connections are 1¼" SAE fluid pads. Drain connection is 9/16"—18 UNF2B thread for ⅜" tube size.

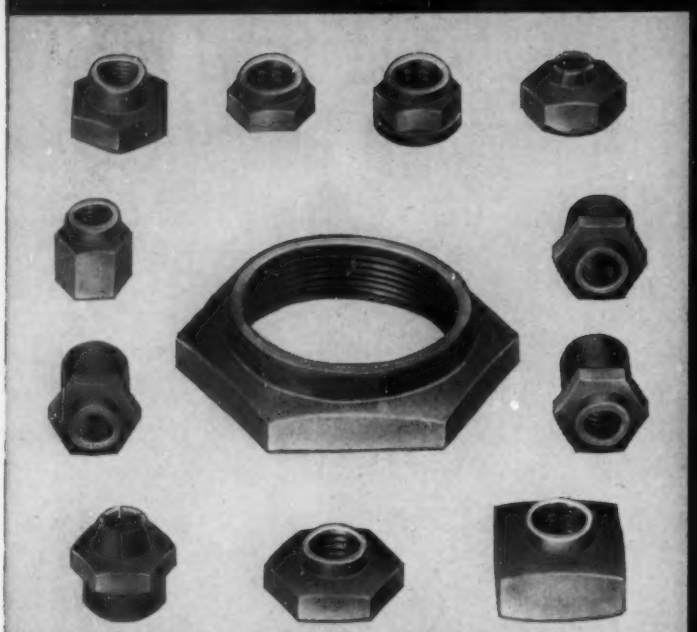
NEW SPECIFICATIONS BULLETIN FOR DESIGNERS AND ENGINEERS

Write for your copy of Bulletin FMV-1 on new Denison M1D Series Vane-Type Fluid Motors. Includes specifications, operating and application data, performance figures on this new 2000 psi equipment.

DENISON ENGINEERING DIVISION
American Brake Shoe Company
1194 Dublin Road • Columbus 16, Ohio

CIRCLE 149 ON READER SERVICE CARD

SPECIAL LOCKNUTS . . . *that solved fastening problems*



As the largest specialized nut manufacturer in the world we are constantly developing new methods and products for this phase of assembly in industry . . . in the field of locknuts we have made spectacular progress. Besides standardized hexagon "Conelok," "Huglock" and "Marsden," sizes #10–3" of ferrous and non-ferrous materials, we provide many special application nuts, upon a basis of these designs . . . a few of which are here shown . . . Our sales and engineering departments are available to help you solve your fastening problems . . . Send for 12-page condensus catalog, it includes complete specifications of our entire product, as well as engineering data. We also have an one hundred and forty four page catalog where more comprehensive information is required.

Manufacturers of Standard and Special ferrous and non-ferrous Hexagon, Square and "12 Pointer" nuts . . . "Conelok," "Huglock" and "Marsden" locknuts.

NATIONAL MACHINE PRODUCTS COMPANY

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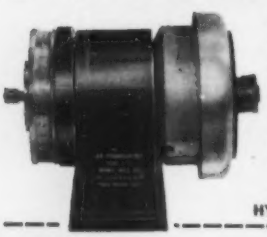
CIRCLE 69 ON READER SERVICE CARD

AN IMPORTANT BREAKTHROUGH IN STANDARDIZED DYNAMOMETERS

HIGH SPEED AIR DYNAMOMETER

By utilizing advanced aerodynamic design principles . . . the new Air Dynamometer pioneered by Hydro-Mill operates on "the air you breathe"! This new concept has helped to expand the capabilities and efficiency of dynamometers. More important, this Air Dynamometer is priced well below conventional units. Tested and proven in laboratory and in the field, the Hydro-Mill Air Dynamometer has proven to have: (a) higher power; (b) a wide "stepless" load range (1:30); (c) higher speeds (32,000-80,000 rpm); (d) direct drive—no gearing required; (e) minimum maintenance.



Manufactured in three standard sizes, with optional subcomponents for any conceivable test requirements. Completely self-contained, self-cooling and compact (5.88", 8.30" or 12.80" O.D.). Write today for prices and complete details.

HYDRO-MILL COMPANY, Santa Monica, Cal.

HYDRO-MILL CO.
1707 Cloverfield Blvd.,
Santa Monica, Calif.

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11. TA Cases are color matched to, and integrated with, the instruments they are to contain.

INSTRUMENT MANUFACTURERS: If you make portable instruments or equipment, you can't afford *not* to investigate the TA line.

TA Cases come in a diversity of standard lid sizes, and are sold at proprietary prices. During assembly the depth can be cut to your exact specifications. Or, if you like, TA will furnish you free vellums and templates so you can save yourself money by designing your product to fit one of the many standard sizes.

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CIRCLE 70 ON READER SERVICE CARD

DESIGN LITERATURE

Optimum Use of Engineering Talent

Edited by JEROME W BLOOD. AMA Report 58. American Management Assn, Inc, 1515 Broadway, New York 36. 6 x 9, 416 pp. $9.00 ($6 to AMA members).

This is the first book we've seen on management of engineers, and it is quite comprehensive. It covers objectives, organization, recruiting, compensation, supervision, professional development and evaluation of the function. Within these broad classifications specific topics are covered by specific engineers, almost in the form of papers. And that's exactly what many of these sections were: papers or addresses at AMA meetings or conferences in the last two or three years. These have been condensed, edited, brought up to date, and new chapters added where necessary to round out the book. Thus some 31 executives combine their talents.

There are case studies, solutions to problems, organization diagrams, discussion of incentives, special treatment, use of technicians and outside help, what management expects and what the manager should expect of himself—a real working handbook in an area where one was needed.—EJT

Value Engineering—Vol 2

RICHARD S MANDELKORN, Editor. Engineering Publishers. Distributed by Reinhold Publishing Corp, 430 Park Ave, New York. 6 x 9, 167 pp. $7.50.

Based on the Second Electronic Industries Assn Conference on Value Engineering last summer, this book is in effect condensations of two dozen papers. Some are heavily electronic-component-oriented, but most contain basic ideas applicable to other components and products as well.

Handbook of Fluid Dynamics

VICTOR L STREETER, editor-in-chief, McGraw-Hill Book Co, Inc, 330 W 42 St, New York 36. 6 x 9; illustrated, 1,240 pp. $24.00.

This thorough, practical handbook answers the need for a one-volume reference library on fluid engineering, and even includes jet and rocket propulsion and magnetohydrodynamics. Key equations, both simple and complex, are included to treat adequately each topic, but derivations are left to the math books.

Over thirty well-known engineers and scientists have contributed the material for this book. Mr. Streeter (editor) is currently Professor of Hydraulics at the University of Michigan. A partial listing of the topics covered is: fluid properties, basic equations of fluid flow, transport phenomena in multicomponent systems, flow of non-Newtonian fluids, compressible flow, boundary-layer theory, turbulence, separation and stall, cavitation, motion of immersed and floating bodies, flow measurement, dimensional analysis, flow through porous media, two-phase flow, sedimentation, turbomachinery, fluid transients in engineering systems; conversion, transmission, and control of fluid power; lubrication mechanics, thermal-jet and rocket-jet propulsion, open-channel flow, the digital computer for fluid-flow calculations, stratified flow, and magnetohydrodynamics.

Modern Production Management

ELWOOD S BUFFA, PH D. John Wiley & Sons, Inc, 440 Park Ave S, New York 16. 6 x 9½, 636 pp. $10.25.

Today's production managers make use of such tools as linear programming, mathematical modeling, statistical analysis, human engineering and depend to a large extent on automation and modern production processes. To make meaningful decisions, they combine these with traditional methods of cost control, scheduling, inventory control and plant layout.

This book integrates the new with the old in a way that is comprehensible to the engineer without placing heavy emphasis on mathematical skill. There are chapters on cost data, simulation models, linear programming, computers and automation, design of work methods, production control, maintenance, and quality control. A variety of charts, tables, graphs, photographs, sketches (even cartoons) supplement the text. The author is Associate Professor of Production Management at UCLA, a consultant for local industrial concerns and managing editor of "California Management Review."

Other Books of Interest

Production Forecasting, Planning and Control

E. H. MacNiece. John Wiley & Sons Inc, 440 Park Ave South, NY 16. 6 x 9¼, 402 pp. $9.75.

The Nature of Thermodynamics

P. W. Bridgman. Harper & Brothers, 49 E 33rd St, NY 16. 5¼ x 8, 239 pp. $1.50

Paperback edition of book originally published 1941, but with a new introduction.

continued, page 152

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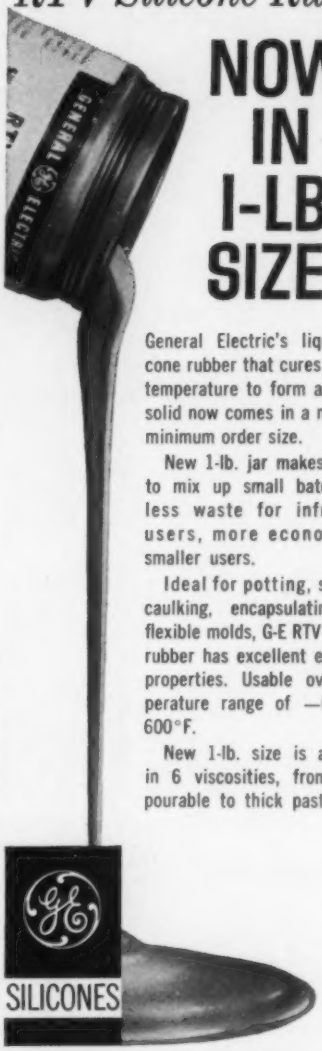

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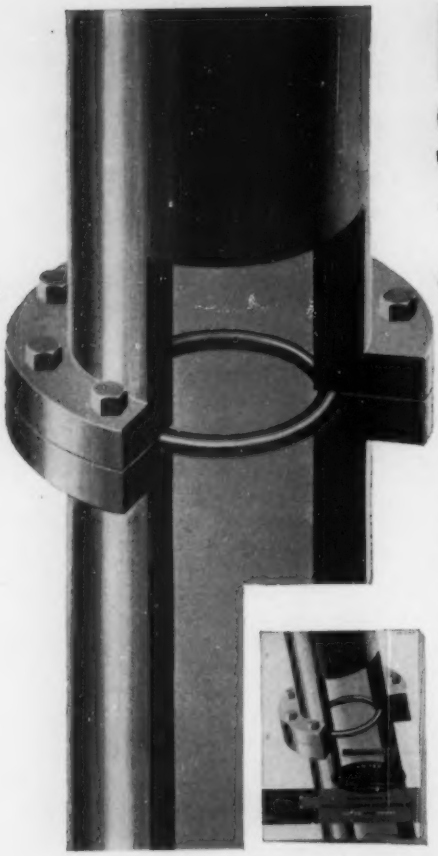

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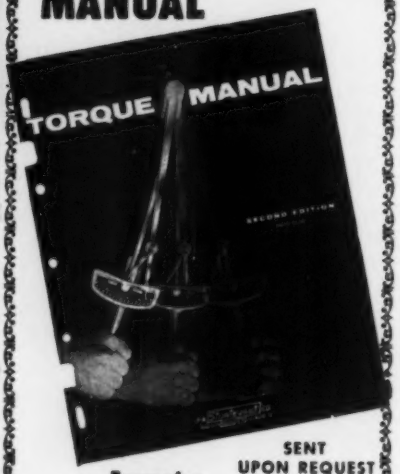

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DESIGN LITERATURE

Guide to US Government Statistics
Documents Index. Box 453, *Arlington* 10, *Virginia.* 8½ *x* 11, 402 *pp.* $15

Practical Electrical Wiring
H P Richter. McGraw-Hill Book Co Inc, 330 *W* 42*nd St, NY* 36. 5½ *x* 8¼, 585 *pp.* $7.95

Readable Relativity
C V Durell. Harper & Brothers, 49 E 33*rd St, NY* 16. 5¼ *x* 8, 146 *pp.* $1.25
Paperback edition of book originally published in 1926, but with a new foreword by the author.

ABSTRACTS

Hydraulic Filter Requirements

Filtration media characteristics are discussed in terms of the requirements of a reliable servo control system. Methods of measuring these characteristics are reviewed. Degree of filtration, nominal efficiency, absolute cutoff, bubble point, dirt capacity, media migration, built-in-dirt, abrasion, channeling, collapse, and element construction are discussed.

Types of depth and surface filter media and their characteristics as related to servo systems, are discussed.

Features and limitations of filter housings are described, and the modular mounting of filter elements in servo packages with differential pressure indicators is discussed and illustrated.

The report concludes with recommendations for filter elements for the protection of servo control systems.

"Hydraulic Filter Requirements of Industrial Servo Systems," John A. Farris, Aircraft Porous Media, Inc. Lubrication Engineering, May '61, 404 *N. Wesley Ave, Mount Morris, Ill.*

Lists of Material

Based on the greater complexity of many of today's manufactured products and their considerably higher engineering content, this article describes new methods of recording the materials and components required for the guidance of production forces and facilities.

"A New Look at Lists of Material," by D. P. Simonton, Graphic Science, July, 1961, *Wilton Center, Wilton, Conn.*

Measuring Frictional Characteristics

A subcommittee of the SAE made up of representatives of automotive transmission manufacturers, oil companies and friction materials producers have conducted a study of some of the factors influencing wet friction. Among the factors considered are lubricant,

temperature, velocity, pressure, friction plate contours, surface finish.

"A New Concept of Measuring Frictional Characteristics," by Smith, Jandasek, Sprague, et al. SAE Paper 363A, Society of Automotive Engineers, 485 Lexington Ave, New York 17.

Thermoplastics

The American author of this article published in an English magazine attempts to show that with reliable engineering data on thermoplastics, the designer is able to remove most of the guess work from plastics design.

"Designing with Thermoplastics," by R. L. Miller, Engineering Materials and Design, August 1961, Drury House, Russell St, Drury Lane, London, WC2.

CATALOGS AND BULLETINS

To obtain copies of literature described below, circle corresponding number on postcard inside back cover.

DRY FLUID DRIVES, COUPLINGS—Bulletin 70, 20 pp. Covers eight stock drives and 11 stock couplings for fractional to 1000-hp requirements, explaining operating advantages and supplying weights, dimensions and prices. Also contains tables of recommended V-belt drives, cutaways and engineering drawings. Dodge Mfg Corp, Mishawaka, Ind.

Circle 350 on Reader Service Card

VACUUM, PRESSURE PUMPS—Catalog 561, 32 pp. Carries details of construction, dimensions, capacities, performance curves, plus engineering and installation data on air pressure and high vacuum pumps, gas boosters and air motors. Models include 2- and 4-vane, single and double cylinder, fancooled, watercooled, aircooled, oilless, motor-driven, belt-driven, direct-coupled, automatically controlled and integral pump and motor. Leiman Bros, 102 Christie St, Newark 5, NJ.

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COMPRESSION TUBE FITTINGS—Catalog 4223, 20 pp. Presents dimensions, working pressures and other specifications of brass and stainless steel fittings with reversible ferrules for tubing of ⅛- to 1-in. OD. Dimension drawings and schematics are included. Parker-Hannifin Corp, Fittings & Hose Div, 17325 Euclid Ave, Cleveland 12.

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ACETAL PLASTIC—Booklet, 24 pp. Describes and illustrates design factors, including strength and toughness; dimensional stability and resistance to

continued, page 155

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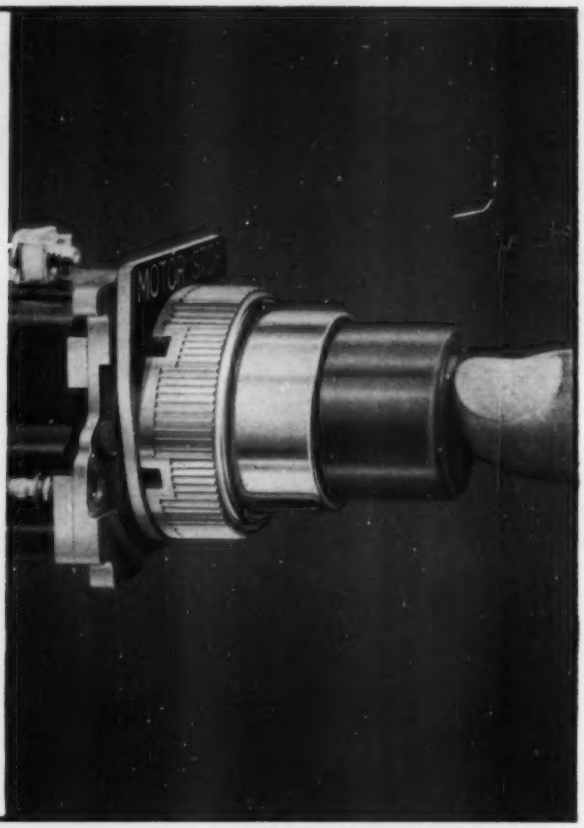

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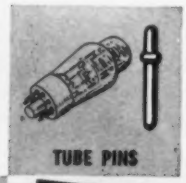

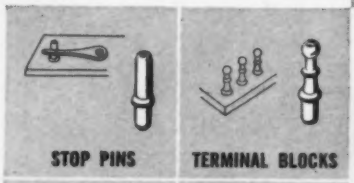

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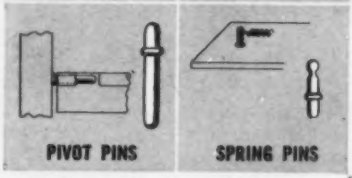

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solvents; fabricating and finishing of both molded and machined parts. Also discusses use of plastic in gears, bearings and electrical applications and design latitudes. Tables of properties and test results are given. Cadillac Plastic & Chemical Co, 15111 Second Ave, Detroit 3.

Circle 353 on Reader Service Card

SYNCHRONOUS MOTORS—Bulletin 1036, 20 pp. Reviews construction and performance characteristics of 385 different types and models. Also contains speed-torque curves, dimension drawings, wiring diagrams, and photos of all motors. Bodine Electric Co, 2500 W Bradley Pl, Chicago 18.

Circle 354 on Reader Service Card

GEAR, PINION COMBINATIONS—Catalog 3001-C, 10 pp. Die cast zinc alloy, one-piece gear and pinion combinations are detailed by engineering drawings and tables showing pitch, number of teeth, pitch diameter and other important dimensions. Over 200 stock combinations are listed. Gries Reproducer Corp, 400 Beechwood Ave, New Rochelle, NY.

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HEAT TRANSFER—Design manual HDM-761, 12 pp. Gives "graphical" solutions in btu's/sq ft/hr and watts/sq ft vs temperature difference for several types of heat transfer problems. Also contains data on heat transfer coefficients and specific heat and thermal conductivities. Electrofilm Inc, 7116 Laurel Canyon Blvd, North Hollywood, Calif.

Circle 356 on Reader Service Card

AIR, HYDRAULIC EQUIPMENT—Digest-size catalog 125, 50 pp. Outlines dimensions, flow capacities, operating pressures and other characteristics of equipment ranging from cylinders, valves and rotating joints to filters, regulators, quick-acting couplers and hose fittings. A Schrader's Son, Div of Scovill Mfg Co Inc, 470 Vanderbilt Ave, Brooklyn 38.

Circle 357 on Reader Service Card

SPECIFICATION BRONZES—Bulletin G-61, 12 pp. Lists nominal chemical and average physical properties, available forms, government and society specifications which alloys meet and some typical applications. Ampco Metal Inc, Box 2004, Milwaukee 1.

Circle 358 on Reader Service Card

ALUMINUM EXTRUSION INGOT—Brochure 28-11596, 12 pp. Lists 19 alloys and details standard sizes,

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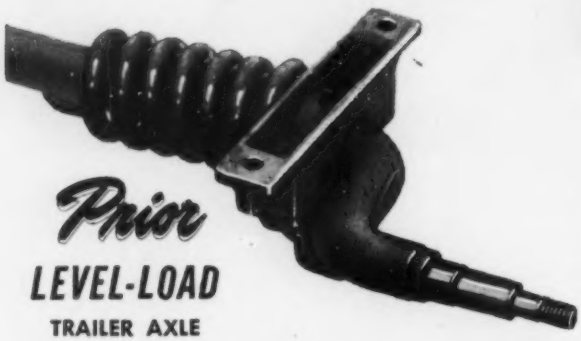

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chemical composition limits, characteristics, typical uses, mechanical properties and recommended thermal treatment. Aluminum Co of America, 726 Alcoa Bldg, Pittsburgh 19.

Circle 359 on Reader Service Card

SILICONE RUBBER MOLD MATERIAL—Bulletin CDS-191, 8 pp. Supplies step-by-step details on use of room temperature vulcanizing liquid silicone rubber for model reproduction and plastic tooling. Includes measuring guide for mixing catalyst with RTV materials. General Electric Co, Silicone Products Dept, Waterford, NY.

Circle 360 on Reader Service Card

RELAY TERM DEFINITIONS—Booklet, approx 14 pp. Reprint of part 10 of American Standards Assn. publication, "American Standard Definitions and Terminology for Relays," C83.16-1959. Prof Charles F Cameron. School of Electrical Engineering, Oklahoma State Univ, Stillwater, Okla.

Circle 361 on Reader Service Card

PLASTICS—Booklet, 16 pp. Spells out results of ASTM tests on styrene, polyethylene, vinyl chloride and molding and extrusion copolymers. Also provides general data on forms, typical uses and characteristics of fabricating, extruding, calendering and laminating materials; industrial, textile, surface and paper coating resins; adhesives and intermediates. Dept FF, Monsanto Chemical Co, Springfield 2, Mass.

Circle 362 on Reader Service Card

AUTOMATIC CLUTCHES—Folder 101, 4 pp. Outlines application classes and ratings, plus specifications and dimensions of direct drive, v-belt and flat belt-type adjustable centrifugal clutches. Power-Max Div, Olme Precision Inc, 484 Masonic Bldg, Portsmouth, Ohio.

Circle 363 on Reader Service Card

EPOXY LAMINATES—Bulletin CDF, 11,200B, 6 pp. Covers laminated epoxy sheets, rods and tubes, giving typical electrical and mechanical properties, sizes and thicknesses. Continental-Diamond Fibre Corp, Newark, Del.

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STRAIN GAGE PRESSURE TRANSDUCER—Bulletin P-61206 and Model 206 service manual, 2 and 8 pp. Former provides specifications,

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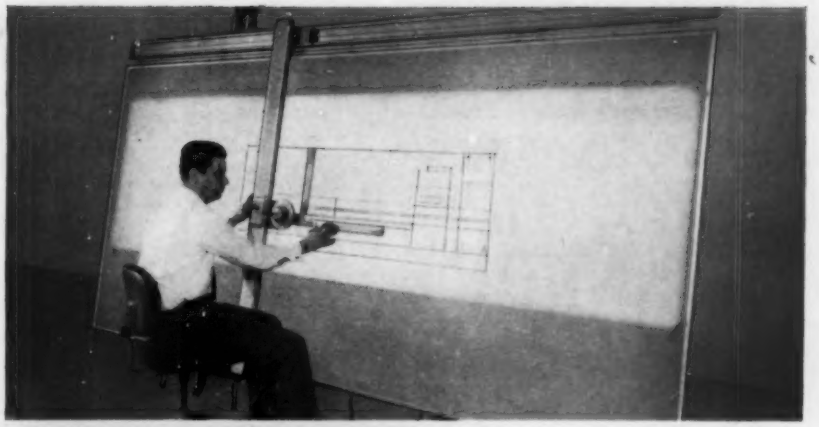

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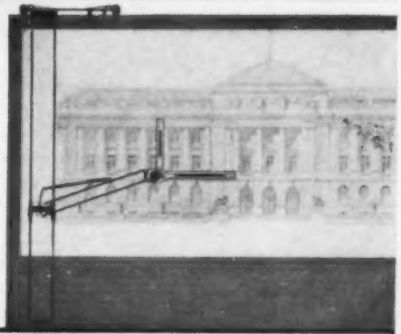

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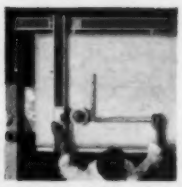

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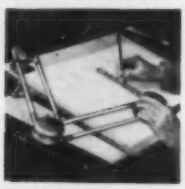

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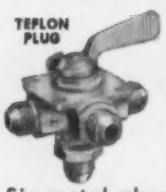

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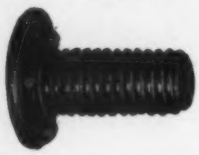

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PUMP FUNDAMENTALS—Booklet 5773-J, 16 pp. Provides elementary outline of characteristics, operation and selection of reciprocating, rotary and centrifugal pumps. Definitions, basic formulas, examples and performance data used in pump application are included. Goulds Pumps Inc, 226 Black Brook Rd, Seneca Falls, NY.

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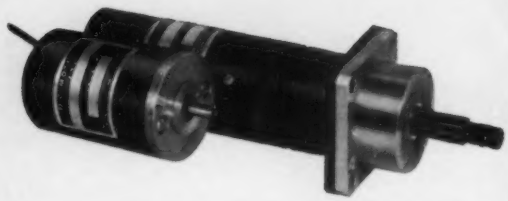

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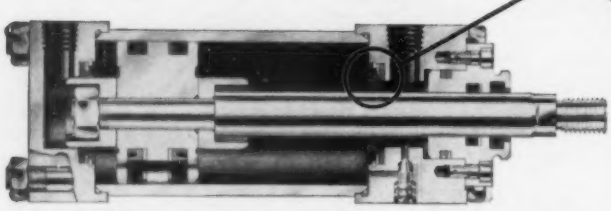

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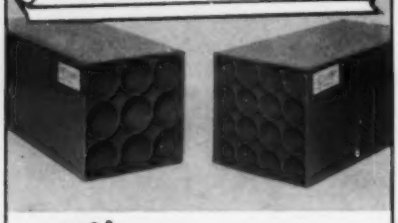

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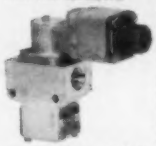

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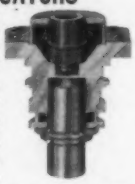

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MAGNETIC DRIVES—Bulletin 3650, 6 pp. Discusses basic components, theory of operation, controls and design features of 50- through 2500-hp units. Specifications and dimensions are tabulated, while curves cover coolant requirements, torque transmission and speed control. Large cutaway is offered. Louis Allis Co, Dept P, 427 E Stewart, Milwaukee.

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DISK INDICATORS—Bulletin 4410, 6 pp. Contains specifications, connection details, diagrams showing typical system applications and a disk indicator selection chart. Electronics & Instrumentation Div, Baldwin-Lima-Hamilton Corp, 42 4th Ave, Waltham 54, Mass.

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ROTARY PUMPS—Catalog, 8 pp. Charts performance and illustrates interior gear construction and placement. Outline drawings appear for several models. Also covered are built-in relief valve, packed box shaft seal and mechanical seal. Roper Hydraulics Inc, Commerce, Ga.

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HERMETICALLY SEALED CONNECTORS—Bulletin T1-3, 4 pp. Outlines specifications of plugs and receptacles designed for high temperature, high pressure, vacuum-seal service. Includes exploded views and dimensional sketch of potting boot assembly. Physical Sciences Corp, 389 N Fair Oaks Ave, Pasadena, Calif.

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Answers to problems on page 140

1. first-order, first-degree, linear, homogeneous.
2. second-order, first-degree, linear, nonhomogeneous.
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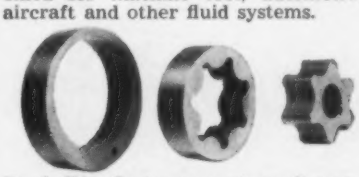

Fig. 1. Three Gerotor components permit pump to be incorporated as integral part of housing or frame of mechanism, eliminate need for purchase and mounting of separate, complete pump.

► **A three-piece insert package makes this economical pump integration possible. Consisting of an inner and outer Gerotor and an eccentric locator-ring, the unit becomes a complete pump by simply boring the casting or frame of the mechanism to accommodate the locator ring O.D. and by providing porting. This design makes the main casting do double duty as the pump housing, thus eliminating a very considerable cost factor. A drive can be taken from any convenient shaft. A simple, positive-acting automatic reversing feature can be built in at little cost.**

► The Gerotor is a form of internal gear pump consisting of only two moving parts: an inner toothed element and an outer, meshing toothed element. The inner element has one less tooth than the outer and the "missing tooth" provides a chamber to move the fluid from the inlet port to the outlet. (See Figure 2). Pump capacity is measured by the volume of the "missing tooth" multiplied by the number of driver teeth and RPM.

FIG. 2

► **The designer thus has the advantage of several variables to secure a given capacity within his space limitations: *Gerotor diameter* — which governs the area of the pumping chamber — *Gerotor thickness* which, taken with area, determines chamber volume — *Gerotor RPM*, since this is a positive displacement pump. Thus, it is possible to vary the diameter, the length and the speed of the pump within certain overall limits to secure the wanted capacity.**

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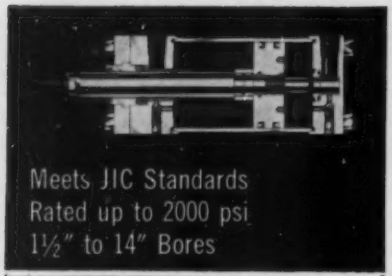

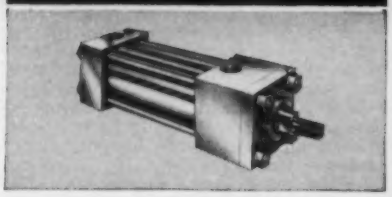

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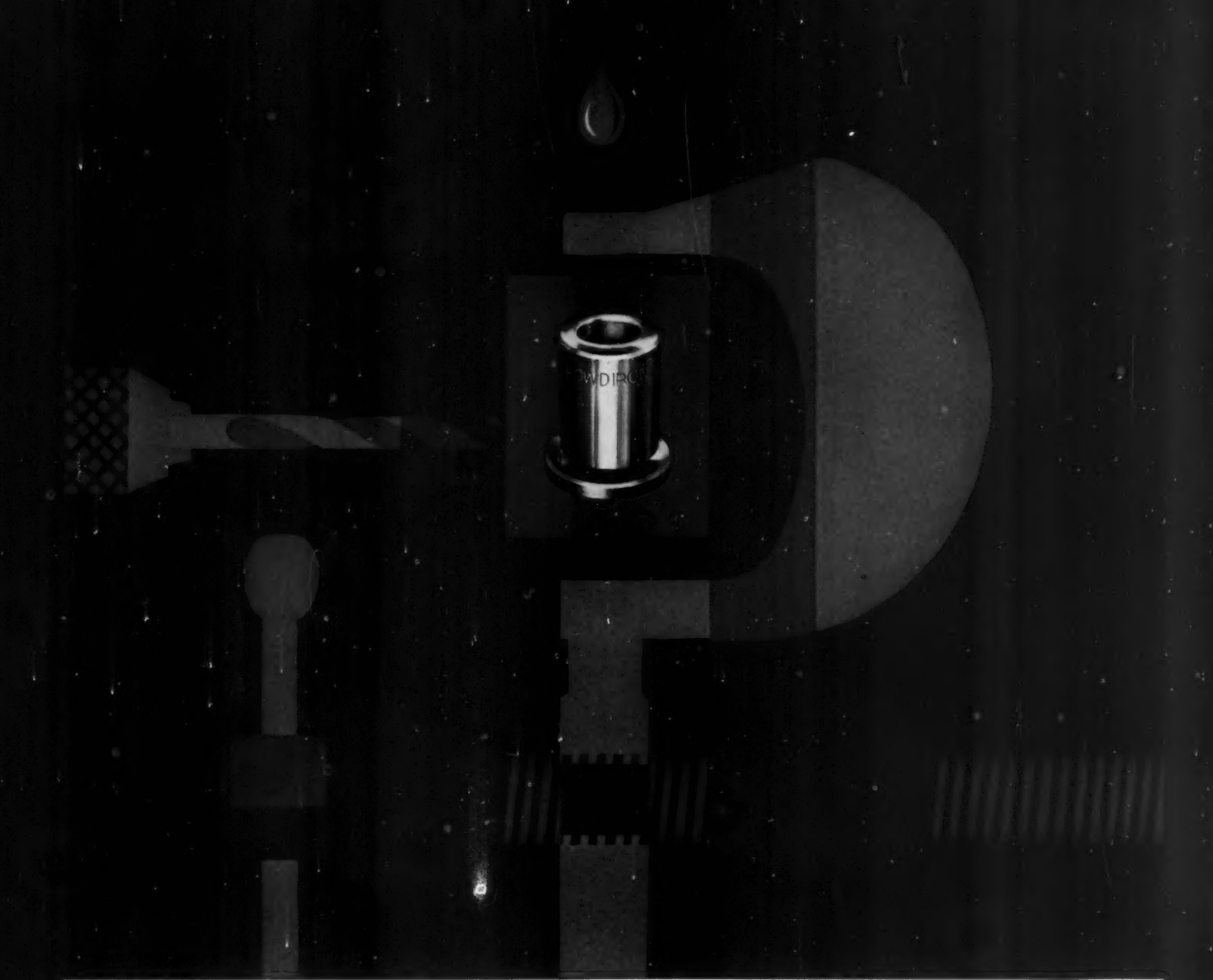

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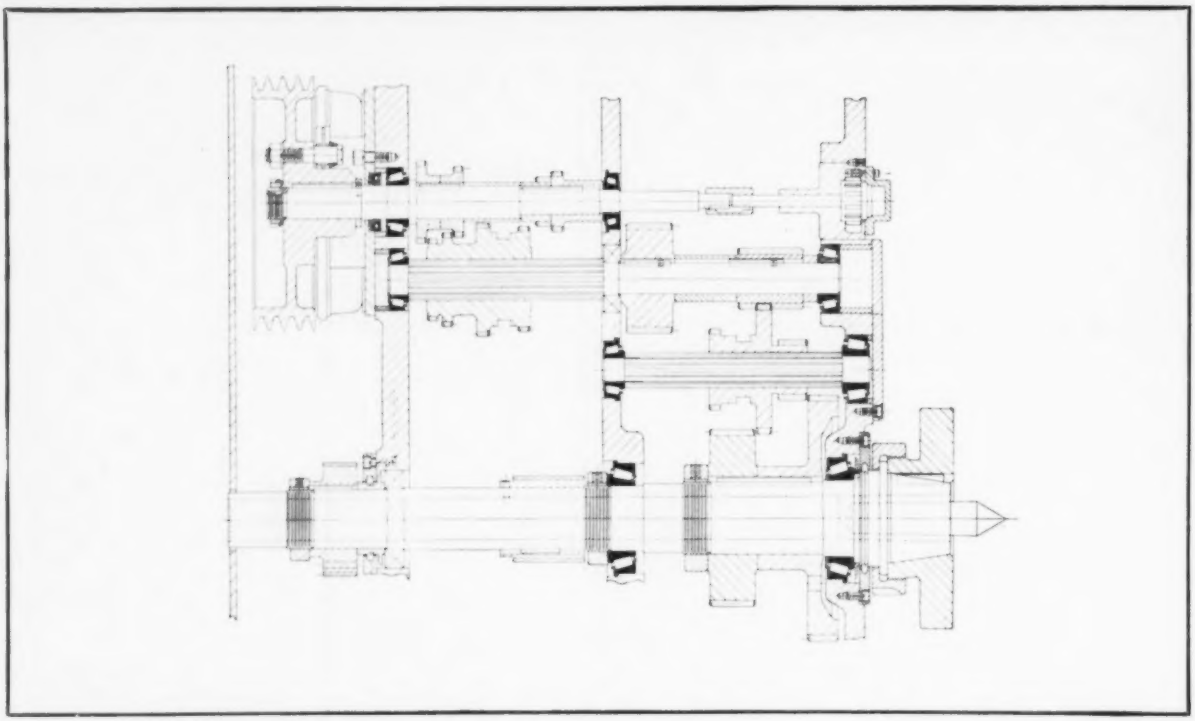
LeBLOND lathe obtains super spindle-runout of less than .000025″ with Timken® "00" bearings



To raise the already great precision of its 15″ Dual-Drive lathe to a special new high for a customer, LeBlond had to meet this requirement: spherocity of the part to be turned—a beryllium gyro float assembly—had to be concentric with its two major axes within .0005″ total indicated runout. Diameter of the sphere: 1.8750″.

To assure this, LeBlond engineers specified Timken® super-precision "00" tapered roller bearings held to .000025″ assembled runout for the spindle—one-third the normal runout tolerance for these bearings. Timken bearings were also used on the intermediate, back and feed shafts of the drive. The assembled spindle runout (total indicator reading) was actually less than .000025″.

Producing super-precision bearings like this is typical of Timken Company service. The kind of service that developed Timken "00" bearings to meet industry's needs for ever-greater precision. It's another example of the Timken Company's leadership in tapered roller bearing design and manufacture.

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